UNIVERSITY OF ALBERTA

PETROLOGY AND MINERALOGY OF THE WATT MOUNTAIN FORMATION IN THE MITSUE - NIPISI AREA, ALBERTA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Petrology and Mineralogy of the Watt Mountain Formation in the Mitsue-Nipisi Area, Alberta", submitted by John William Kramers, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The Watt Mountain Formation and its Gilwood Sandstone Member in the Mitsue-Nipisi area is of Middle Devonian age. Cores from twelve wells in the Mitsue area and two from the Nipisi area were described with the aid of a binocular microscope. The Watt Mountain Formation consists of interbedded sandstone and mudstone, with a dolomite unit near the base of the formation. Eighteen sandstone thin sections from the Mitsue area and ten from the Nipisi area were studied for sandstone petrography. Ten samples from one well in the Mitsue area were examined for mudstone mineralogy by means of X-ray diffraction and differential thermal analysis.

The Gilwood Sandstone Member is mainly a feldspathic sandstone in the Mitsue area and an arkose in the Nipisi area. Carbonate is the primary cement in the sandstones and partly replaces the matrix; this carbonate in turn is partly replaced by anhydrite. The sandstones are poorly to moderately well sorted. A test size analysis study, comparing sieve data with thin section data, showed that for these sandstones the two methods cannot be reconciled using Friedman's conversion factors.

The brown to green mudstones of the Watt Mountain Formation are relatively simple mineralogically, consisting mainly of quartz, dolomite, feldspar, illite, chlorite, and minor amounts of anhydrite. The color is not related to iron content but probably is related to the oxidation state of the iron.

The composition of the Gilwood sandstone indicates that the source area was primarily an igneous-metamorphic terrain, most probably the Peace River High. The environment of deposition of the Watt Mountain Formation, in the area of study was near-shore, deltaic or coastal plain, probably ranging from shallow marine to continental. Differences in the composition of the Gilwood sandstone between the Mitsue and Nipisi area are probably due to different distances of transport and slightly different environments of deposition.

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INTRODUCTION

General Statement

The area of study is shown in Figure 1 and encompasses the Mitsue and Nipisi oil fields about 150 miles north-northwest of Edmonton, Alberta. Twelve cored wells from the Mitsue field and two from the Nipisi field were studied. Descriptions of eleven of the Mitsue wells and one from the Nipisi field are given in Appendix A. The names and locations of all wells are shown in Table I.

The main emphasis of the study has been on the cores from the Mitsue field, eleven of which are shown on cross-sections A-A' and B-B' (Figure 2). The cores from the Nipisi field were used for a comparison of the petrology of the Gilwood sandstone as the Peace River High is approached.

The objective of this study can be summarized as follows:

1. To describe the lithology of the Watt Mountain Formation.
2. To study the detailed petrology of the Gilwood sandstone.
3. To determine the mineralogy of the 'shales' of the Watt Mountain Formation.
4. To evaluate the provenance and depositional origin of the Watt Mountain Formation in the area of study.

Method of Investigation

As no previous detailed work on the Watt Mountain Formation has been published, the study was undertaken on a step by step basis. It was initiated by systematically sampling and describing cores of the Watt Mountain Formation from the wells listed in Table I. Following this, two cross-sections were drawn (Figure 2), and samples were chosen for further detailed study.

Thin sections were cut of 28 selected sandstone samples, eighteen from four wells in the Mitsue field and ten from the two wells in the Nipisi field, and these were used to describe the petrology of the Gilwood sandstone. Samples were chosen

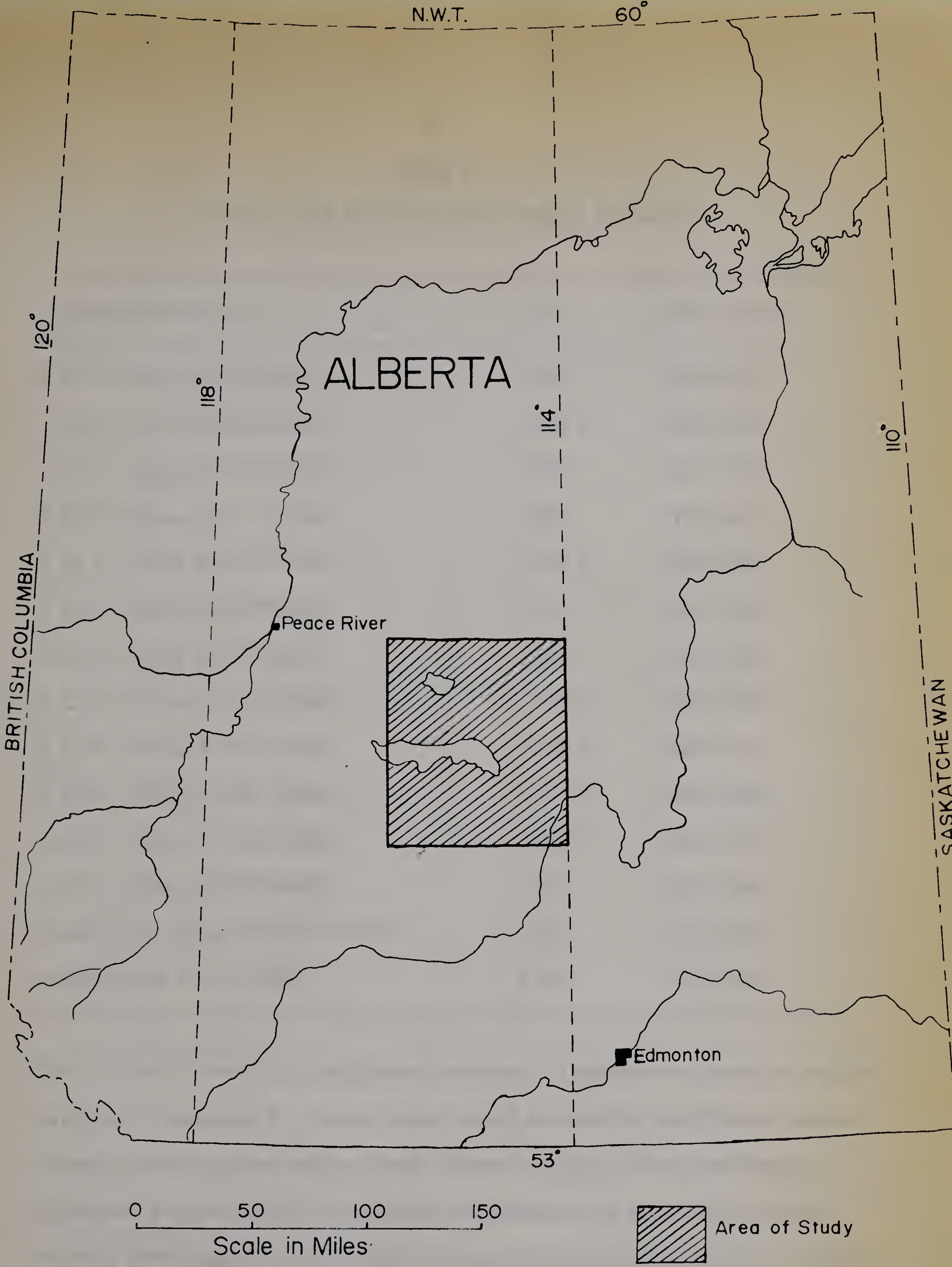

Figure 1. Location Map

TABLE I

NAMES AND LOCATIONS OF WELLS EXAMINED

Name and Location	K.B.	Cored Interval
I.O.E. Mitsue 4-4-73-4W5	1925	5310-5361
I.O.E. Sylvia 10-6-73-4W5	1900.5	5320-5371
I.O.E. Mitsue 12-7-73-4W5	1915	5334-5394
I.O.E. Mitsue 12-1-73-5W5	1907	5372-5419
I.O.E. Sylvia 12-3-73-5W5	1911.5	5407-5481
I.O.E. Sylvia 10-5-73-5W5	1911.1	5461-5540
I.O.E. Sylvia 2-6-73-5W5	1915.7	5518-5582
I.O.E. Sylvia 12-13-73-5W5	1903.8	5330-5387
I.O.D. Mitsue 4-23-73-5W5	1909.9	5336-5416
I.O.E. Mitsue 10-28-73-5W5	1917.9	5386-5440
I.O.E. Mitsue 4-35-73-5W5	1910.3	5329-5379
I.O.E. Sylvia 10-3-73-6W5	1914	5601-5684
Mobil S.W. Nipisi 10-26-78-8W5	2158	5610-5680
Mobil Nipisi 7-6-79-7W5	2180	5595-5655

from the entire interval of the Gilwood Sandstone. Locations and depths of samples are given in Appendix B. A point count method was used for quantitative compositional evaluation after staining potash feldspar using the method described by Hayes and Klugman (1959). Additional thin-sections were also made for further study of what appeared to be interesting features noted during preliminary description of the cores.

The mineralogy of the 'shales' in the Watt Mountain Formation was studied by means of X-ray diffraction and differential thermal analysis. The Chittick

apparatus (Dreimanis, 1962) was used to determine the carbonate content. One well was chosen for this purpose, and ten samples examined.

An isopach map (Figure 8) showing the net feet of sand in the Watt Mountain Formation as determined from electric logs[1], and a cross-section showing the relationships of the Watt Mountain Formation and the Basal Red Beds as the Peace River High is approached (Figure 9), were drawn in order to get a more regional picture and to aid in the evaluation of the depositional history of the Watt Mountain Formation.

Previous Work

To date, no detailed papers exist dealing with the Watt Mountain Formation in the present area of study, as far as the writer is aware. Much research has been done, however, by oil company personnel on the Gilwood sandstone since the discovery of oil in this unit in the Mitsue area, by Chevron Standard Limited in February, 1964. Most of this data will probably remain locked in the confidential files of the oil companies for some time as the area is not yet completely developed.

Law (1955) defined the Watt Mountain Formation, and the Gilwood Sandstone Member was defined by Guthrie (1956). Suska (1963) in her study of the Elk Point Group and Cambrian rocks of North-central Alberta, did a regional analysis of the Watt Mountain Formation. Other authors have mentioned the Watt Mountain Formation in passing, but no other detailed accounts have been given in any published reports.

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[1] Outside the Mitsue, Nipisi and Utikuma fields, control points are restricted to wildcat wells.

STRATIGRAPHY

Definitions of Stratigraphic Units

Regional correlation of units near the Middle-Upper Devonian boundary is shown in Table II.

The Watt Mountain Formation was defined by Law (1955) as:

> "the uppermost unit of the Elk Point.....it consists of a maximum of 155 feet of shale, siltstone, sandstone, arkose, limestone breccia, anhydrite and dolomite. The lithologic character of the unit is controlled to a large extent by the distance from the Peace River landmass." (p. 1951)

The type section designated and described by Law is in California Standard's Steen River No. 2-22 well, located in Lsd. 2, Sec. 22, Twp. 117, Rge. 5, W6 Mer., from a depth of 4452' to 4513', and is completely cored.

The upper and lower contacts of the Watt Mountain Formation were defined by Law as follows:

> "The top of the Watt Mountain Formation in Northern Alberta is placed at the top of a sequence of terrigenous clastics or limestone breccia below anhydrite, or, less commonly, limestone of the Slave Point Formation. The base of the formation is placed at the contact between the clastic beds and massive dolomite of the Presqu'ile Formation, or bedded evaporites and carbonates of the upper evaporitic unit (Muskeg formation)." (p. 1952).

The Gilwood Member of the Watt Mountain Formation was defined by Guthrie (1956) as being,

> "restricted to the outwash of arkosic sands over the surface of older formations which are wedged out against the old Peace River land mass." (Workman, *et al.*, 1960, p. 146).

The type section designated and described by Guthrie is at the Stanolind Giroux Lake No. 1 well, located in Lsd.6, Sec. 20, Twp. 65, Rge. 20, W5 Mer., at a depth of 10,068 to 10,102 feet (cored intervals are 10,075 to 10,079 and 10,080 to 10,125). Suska (1963) referred to the Gilwood Sandstone rather than the Gilwood Member, and this terminology has since been widely used in the petroleum industry in Western Canada. It is thus referred to as the Gilwood Sandstone Member of the Watt Mountain Formation in this thesis.

AGE	GREAT SLAVE LAKE AREA (Norris, 1965)	WATT MOUNTAIN TYPE SECTION (Law, 1955)	MITSUE - NIPISI AREA	SASKATCHEWAN & MANITOBA (A.S.P.G., 1964)
UPPER DEVONIAN	SLAVE POINT Fm. Amco sh.	SLAVE POINT Fm.	SLAVE POINT Fm.	SOURIS RIVER Fm.
?				
MIDDLE DEVONIAN	WATT MOUNTAIN Fm.	WATT MOUNTAIN Fm.	WATT MOUNTAIN Fm.	FIRST RED BEDS
	SULPHUR POINT Fm. / PRESQU'ILE Fm.	PRESQU'ILE Fm.	MUSKEG Fm.	DAWSON BAY
				SECOND RED BEDS
				PRAIRIE EVAPORITE

TABLE II Regional Correlations of Units near the Middle-Upper Devonian Boundary.

Age and Correlation of the Watt Mountain Formation

The Watt Mountain Formation, according to Law (1955), is represented in the Pine Point area of the Northwest Territories by the Amco 'shale' and the underlying beds down to the top of the vuggy dolomite described by Campbell (1950). However, Norris (1965) puts the Amco 'shale' at the base of the Slave Point Formation. Norris also reports that the Watt Mountain is present in the subsurface of the Great Slave Lake area, where it lies between the top of the Sulphur Point Formation and the base of the Slave Point Formation.

At the type area of the Elk Point Group at Elk Point Alberta, (McGehee, 1949), the Watt Mountain Formation is equivalent to a 50-foot unit of red and green shale and 5 feet of siltstone overlying the first salt (Law 1955, p. 1954).

In Saskatchewan and Manitoba the Watt Mountain is correlated with the First Red Bed unit, which is red to green, dolomitic, partly silty shale (Grayston, *et al.*, 1964).

The age of the Watt Mountain Formation is Middle Devonian (Givetian), (Grayston, *et al.*, 1964). A controversy exists over the position of the Middle-Upper Devonian boundary. The convention of Grayston, *et al.* (1964) is followed here, the Middle-Upper Devonian boundary being placed at the top of the Watt Mountain Formation, with the realization that Warren and Stelck (1962), McGill (1966) and Braun (1966) prefer to put the boundary at the top of the Slave Point Formation.

Fauna found in the cores examined by the writer include:

- *Cyzica* (=*Estheria*) cf. *membranacea*
- *Eochara wickendeni*
- *Chovanella burgessi*
- Fish plates and scales of antiarch (cf. *Bothriolepis*), *Pterichthyodes*, ganoides and cephalaspids

Also found are the remains of the flora *Psilophytes*.

Suska (1963) reported the finding of crinoids, brachiopod fragments, chara and *Trochiliscus* (?) sp.. Guthrie (1956) reported several ostracods and fish scales

from the type section of the Gilwood Sandstone, the ostracods suggesting a Middle Devonian affinity. The fish scales were compared by Guthrie to those of Acanthodes (Devonian) of the British Isles. Suska (1963) also reported (by personal communication from the geological staff of Pan American Petroleum Corporation, 1958) that a Middle Devonian fauna was collected from cores of the Gilwood Sandstone at the Stanolind House Mountain No. 1 well (Lsd. 7, Sec. 29, Twp. 70, Rge. 13, W 5 Mer.).

General Lithology

Cross-sections A-A' and B-B' (Figure 2) show the lithology of the Watt Mountain Formation in the Mitsue area. For the purpose of a general lithologic description, the Watt Mountain Formation is broken down into six subdivisions, and these are described from base to top. At this point it is emphasized that these are not formal subdivisions of the Watt Mountain Formation, but are used for the sake of convenience in describing the general lithology of the formation.

Upper Portion of the Muskeg Formation

Argillaceous anhydrite to very anhydritic mudstone, mainly dark greenish gray, with inclusions of pure anhydrite which may be of intraformational breccia origin; some of the rounded inclusions appear to have what may be a reaction rim which is yellowish orange to dusky red; boundary with mudstone above is gradational to quite sharp. This interval is similar in all the wells of the Mitsue area that were studied.

Watt Mountain Formation

Unit 1

Mudstone, silty and sandy in part, anhydritic to calcareous, mainly greenish gray, but may locally be brownish gray due to mottling and discoloration; appears uniform in composition with no sedimentary structures. In the 12-3-73-5W5 well this unit grades into a muddy and sandy siltstone in the upper half. There may be some replacement by anhydrite. Fragments of Cyzica (Estheria) occur in the 10-3-73-6W5 well in this interval.

Unit 2

Dolomite with some interbedded shales at the base and top of the interval; dolomite is argillaceous in part, anhydritic or partly replaced by anhydrite, light olive gray to pale yellowish brown, aphanitic for the most part, has some limestone

fragments in the upper part in the 4-4-73-4W5 and 4-23-73-5W5 wells. Anhydrite replacement may be parallel to bedding surfaces as in the 10-6-73-4W5 well and disrupt the dolomite into blocks, or it may be in the form of pods of anhydrite as in the 4-4-73-4W5 well. Shale bands are usually dark greenish gray, slightly fissile and fossiliferous in the upper part. Cyzica, antiarch scales and ganoid type scales and other unidentifiable fish remains are present. This unit usually grades into the mudstone (unit 1) below and sometimes grades into the unit above. The upper part of the unit is in all cases dark greenish gray shale which has locally some sandy and silty zones in it (less than 1/2 cm.) and thus may grade into the unit above by interbedding .

Unit 3

Interbedded to laminated sandstone and siltstone to silty sandstone or sandy siltstone, calcareous in part, light greenish gray to dark greenish gray depending on mudstone content. The sand varies from very fine to very coarse grained with some granules occurring locally, but usually is fine to medium grained, moderately sorted, subangular to subrounded. The unit shows many sedimentary structures such as scour, organic reworking, small fractures, laminations, sublaminations, pinch and swell of shaly streaks and slump. The composition of sand and silt size material is mainly quartz and feldspar but there are shale fragments locally in the upper part of the unit. Accessory minerals are mica, chlorite and glauconite. The unit may have lenses of mudstone which split it into two parts, and the upper part may shale out locally. This mudstone is dark greenish gray with local grayish brown mottling and discoloration. There may also be dolomite bands running through either the mudstone or interbedded siltstone, mudstone and sandstone. These are usually only 0.3-0.5 feet in thickness and thus are probably of local extent. In the 10-3-73-6W5 well the dolomite has some interbedded shale laminae in it. Even if no central mudstone break exists, the unit is usually divisible into two parts with the upper part usually appearing more reworked than the basal. The thickness of this unit varies and appear to be greater in areas that were low at the time of deposition of the top of the Watt Mountain. The unit locally contains Cyzica, antiarch scales and Psilophytes (plant remains), but none of these are abundant.

Unit 4

Mudstone, silty and sandy in part, calcareous in part, anhydritic in part, dark greenish gray with brownish gray mottling and discoloration; discoloration appears in zones and some mottling may be due to brecciation during compaction; locally sandy and silty zones exist. This unit is fairly uniform and appears to be extensively reworked; locally it has sublaminations and laminations (4-23-73-5W5). Unidentifiable fish remains occur locally, also glauconite and mica in some cores.

Unit 5 Gilwood Sandstone Member

Sandstone, argillaceous and silty in part, conglomeratic in part (e.g., in basal part of 4-23-73-5W5), partly anhydrite plugged, calcareous in part, pale yellowish gray to light gray; fine to coarse grained in general (with zones of up to granule size grains), angular to rounded (most commonly subangular to subrounded) with scattered well rounded grains (especially in granule size), moderately well to poorly sorted, cross-bedded in part (planar and trough types), sometimes with basal scour on a shaly zone and inclusions of shale chips, laminated locally in finer grain sizes, with some reworking; some interbedding of coarser, poorly sorted sandstone with finer, well to moderately sorted sandstone. Anhydrite plugging appears

to be mainly concentrated in the coarser grained intervals where there is also some minor calcareous cement. The composition is mainly quartz with some feldspar and shale chips, accessory minerals being, mica, glauconite and scattered pyrite. Some fossil fragments are found in the sandstone but are only identifiable as pieces of bones and plates. There can be intervals of mudstone especially near the pinch out edge of the Gilwood, where up to three shale units are shown in the cross sections. In well 4-23-73-5W5 a muddy conglomerate zone also occurs which is very poorly sorted, with angular to subrounded grains up to granule size. The interval is made up of several conglomerate bands in a mudstone, throughout which there are floating granule size grains. The composition is mainly quartz with some feldspar and shale chip rock fragments.

Mudstone Units in Gilwood Sandstone

A.- Mudstone, silty and sandy in part, slightly calcareous and anhydritic, dark greenish gray with moderate brown mottling and discoloration, structureless, grades into sandstone above and below; either shales out or pinches out laterally to the west and northwest; Cyzica is the only fossil remains found.

B.- Mudstone, silty in part, dark greenish gray to greenish gray with grayish brown mottling and discoloration throughout interval, slightly calcareous and anhydritic, grades into sandstone above and below by interbedding or by progressively becoming sandy. This is the major mudstone unit in the B-B' cross-section and it appears to pinch out to the west in the A-A' section. Fossils found in this band are Cyzica, Eochara wickendeni and Chovanella burgessi, antiarch plate and a cephalaspid-type plate. There is also some mica and glauconite as accessory minerals scattered through the interval.

C.- Interbedded sandstone and mudstone, silty, anhydritic, light gray and light greenish gray for the sandstone to dark greenish gray for the mudstone; sandstone is very fine to very coarse grained, angular to rounded and poorly sorted, shows cross bedding and scour in th 12-7-73-4W5 well, reworked laminations in the 12-1-73-5W5 well and wavy non-continuous laminations in the 10-6-73-4W5 well. The composition of the sand is mainly quartz and feldspar with some shale chips; accessories are glauconite, pyrite and mica.

D.- Mudstone, silty in part, calcareous and anhydritic in part with some sandy interbeds in the 2-6-73-5W5 well, dark greenish gray with some red mottling in the 2-6-73-5W5 well; sand grains scattered throughout, structureless except for the interbedded sandstone and siltstone, which is shaly, yellowish gray to dusky yellowish gray, very fine to fine grained in some intervals and medium to granule size in others with some scattered pebbles; coarse material is poorly sorted; microfractures and minor scour; grades into sandstone above fairly sharply and into sandstone below by means of interbedding in the 2-6-73-5W5 well. There are some scattered fish remains, which are probably plates.

The Gilwood Sandstone in the 10-28-73-5W5 well also contains a 0.4 feet dolomite unit which is shaly, light olive gray to olive gray, aphanitic, partly anhydrite replaced and scattered pyrite.

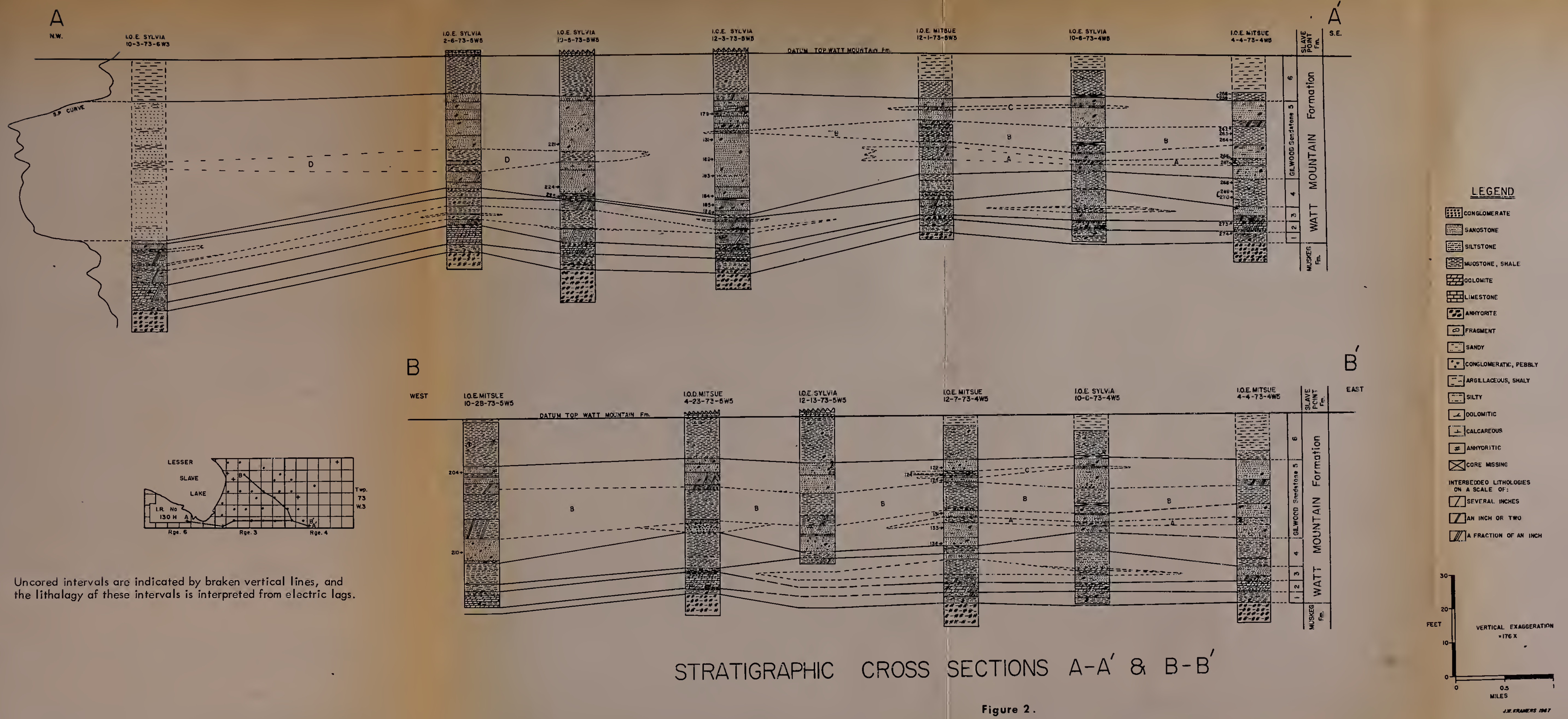
Unit 6 Upper part of Watt Mountain Formation

Mudstone, silty in part, calcareous in part, anhydritic in part, dark greenish gray

to greenish gray depending on silt content; fairly uniform throughout with some sub-laminations that occasionally have been partly reworked; locally scattered pods of anhydrite. Possible organic remains are present, but cannot definitely be identified. This unit usually grades into sandstone below either by interbedding (12-3-73-5W5) or by becoming silty and sandy in the basal 0.5 feet. In some wells pyrite appears as an accessory mineral.

Lower part of the Slave Point Formation

Limestone, anhydritic, argillaceous, with some shaly and anhydritic bands, olive black to dark greenish gray, aphanitic to micro-crystalline; laminations, sub-laminations, pinch and swell of calcareous shale laminae, brecciation in upper parts and scour. A dolomite band about 0.5 feet thick at the base is argillaceous, light gray to olive gray, partially anhydritic, aphanitic, laminated in part, shows scour, brecciation. This unit is very similar in all the wells in which it is present in the core and probably represents stable and uniform conditions in the Mitsue area.



STRATIGRAPHIC CROSS SECTIONS A-A' & B-B'

Figure 2.

SANDSTONE PETROGRAPHY

Size analysis

Four samples from the Gilwood sandstone were analysed in order to get an approximate idea of the grain size distribution and to compare the point count method with the sieve analysis method.

For the point count method (Chayes, 1954), a calibrated micrometer was used, and the longest apparent axis of each grain was measured. Points were spaced 0.4 mm apart in order to cover a large area of the thin section. The total number of points counted per thin section varies because counting continued until a total of one hundred quartz grains had been recorded.

The sieve analysis required disaggregation of fairly well-cemented sandstone. Acid treatment was used as it was felt that this would not affect the sand and silt fraction, which is mostly quartz and feldspar. The samples were first carefully crushed to pea size, and the cement dissolved by the following treatment:

a - 12 hours in warm hydrochloric acid.

b - 1 hour in boiling sodium thiosulphate.

c - 12 hours in hot nitric acid.

The disaggregated sample was then examined under a binocular microscope to make sure that all the cement was dissolved, and then weighed. It was then wet sieved on a 325 mesh screen after the clay minerals had been dispersed. The +325 mesh material was sieved, using a 0.5Ø screen interval, on a Rotap machine for fifteen minutes.

Results

Cumulative curves were plotted on probability ordinate paper (Figure 3), using the phi notation for grain-size (McManus, 1963). The size data from the cumulative curves are shown on Table III. Histograms of both the thin section and sieve analysis data were also constructed (Figure 4). For each sample three sets

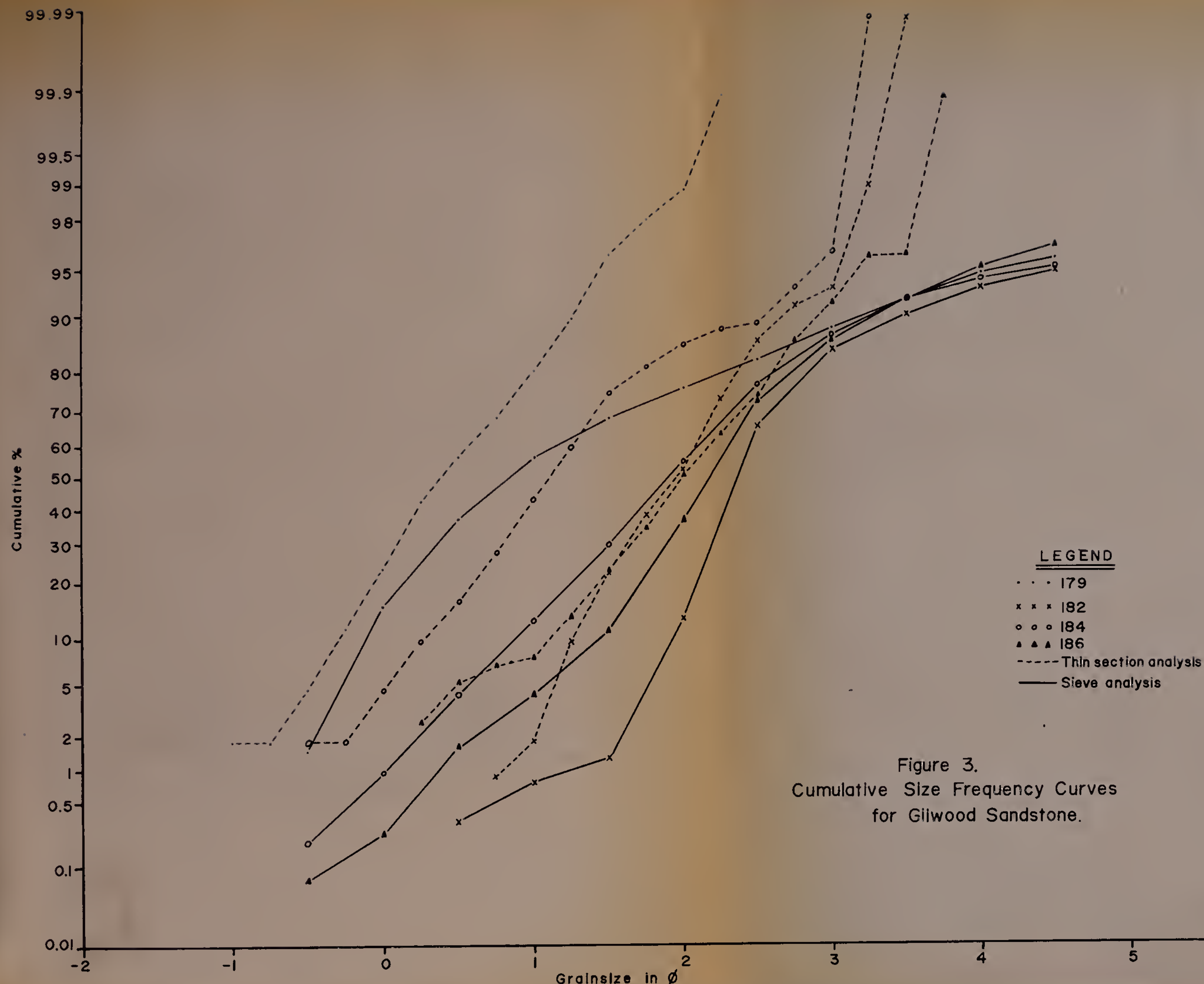


Figure 3.
Cumulative Size Frequency Curves
for Gilwood Sandstone.

TABLE III

SIZE DATA FROM CUMULATIVE CURVES

Sample Number	Ø5	Ø16	Ø25	Ø50	Ø75	Ø84	Ø95
179a[1]	-0.27	0.03	0.25	0.84	1.92	2.43	3.96
179b[2]	-0.48	-0.14	0.03	0.38	0.88	1.08	1.43
179c[3]	-0.05	0.32	0.40	0.71	1.17	1.36	1.67
182a	1.77	2.04	2.15	2.36	2.70	2.90	4.37
182b	1.14	1.42	1.54	1.95	2.28	2.44	3.04
182c	1.40	1.66	1.77	2.14	2.45	2.60	3.13
184a	0.57	1.08	1.38	1.89	2.43	2.69	4.20
184b	0.03	0.49	0.70	1.10	1.50	1.89	2.85
184c	0.40	0.82	1.05	1.36	1.74	2.10	2.96
186a	1.08	1.60	1.81	2.17	2.55	2.80	3.88
186b	0.48	1.29	1.54	1.98	2.50	2.68	3.15
186c	0.80	1.55	1.77	2.18	2.65	2.80	3.24

1. Size data from sieve analysis.
2. Size data from thin section point counts.
3. Converted size data from thin section point counts using Friedman's (1958) chart to convert thin section data to sieve-size data.

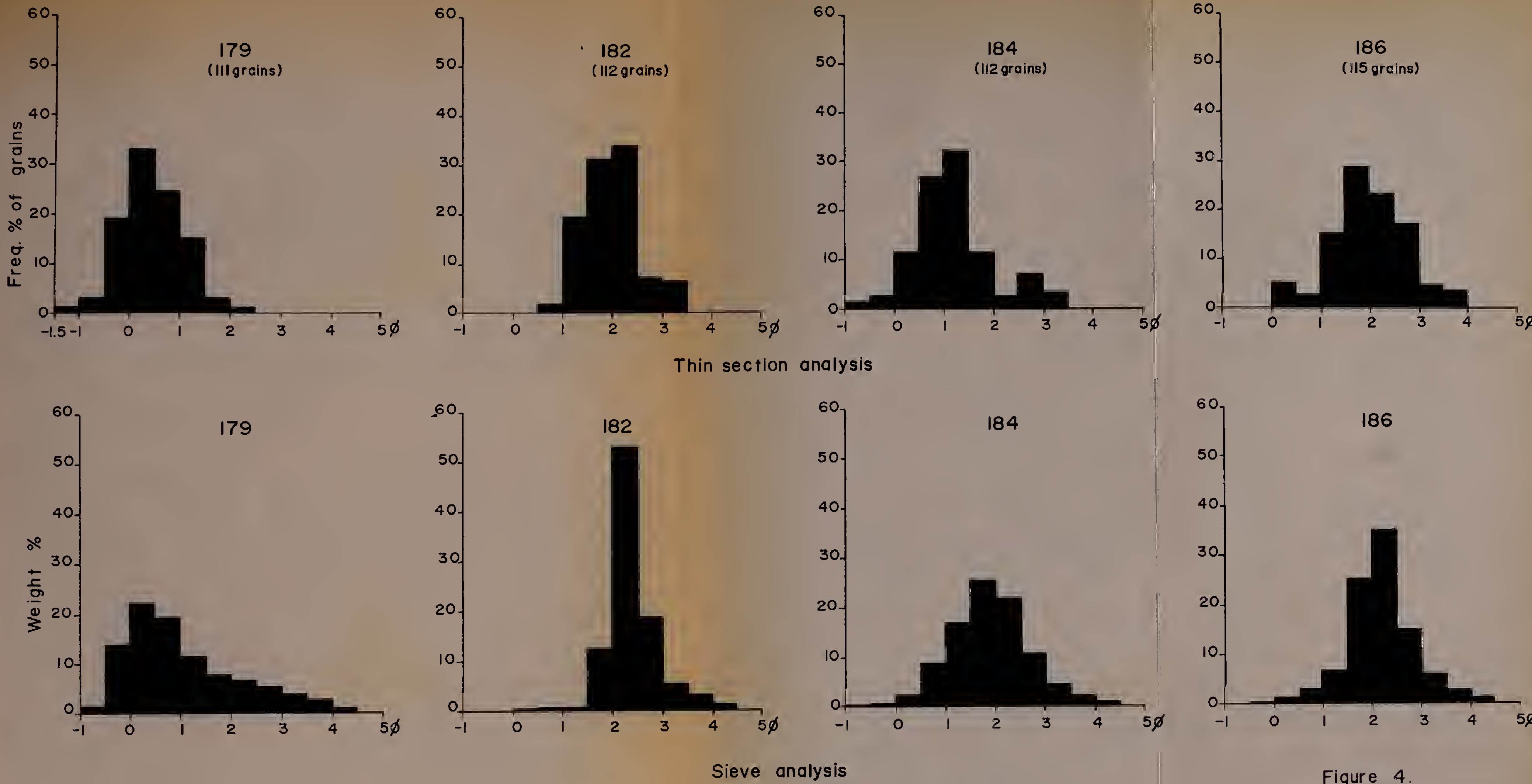


Figure 4.
Histograms showing Size Frequency Distributions of Gilwood Sandstone

of data are presented:

a - size data from sieve analysis.

b - size data from thin section point counts.

c - converted data from thin section point counts using Friedmen's (1958) chart to convert thin section data to sieve-size data.

Table III shows that the "average" grain size of the samples (Ø50) ranges from 0.84Ø to 2.36Ø for the sieve data and from 0.38Ø to 1.98Ø for the unconverted thin section data. According to Folk's (1964, p. 45) classification, these four samples are moderately well to poorly sorted. Conclusions from visual observation through the binocular microscope agrees with this. Cursory examination of Figure 4 shows that the size distributions of these samples are nearly symmetrical (#184, sieve analysis) to strongly fine-skewed (#179, sieve analysis).

Discussion of Results

As can be seen from Table III and Figures 3 and 4, the thin section data show the samples to be coarser grained than do the sieve analysis data. This is in accord with the theoretical presuppositions of van der Plas (1962), and is what was expected, because in thin section the diameter measured is between the largest and intermediate axis, while sieve analysis more nearly measures the intermediate grain axis. Friedman (1958) published a chart for converting thin section data to sieve-size data. This resulted in a discussion between Friedman and van der Plas (Friedman, 1965a, 1965b, and van der Plas, 1965) of the validity of this conversion. Sample numbers with c designation in Table III are the converted thin section data, and it is apparent that Friedman's (1958) conversion factors are not valid for the Gilwood sandstone. However, it was not expected that this factor would necessarily apply to quartz-poor sandstones as the following statement by Friedman shows:

> "The samples used for this study represent sandstones containing more than 70 percent quartz. For rocks which have a much lower quartz content, the simple correction offeredin this study need not necessarily apply" (Friedman 1958, p. 413).

It is therefore concluded that in the case of the Gilwood sandstone, it is not possible to convert thin section-size data to sieve-size data by means of published conversion equations.

Composition

The point count method (Chayes, 1954) was used to analyse twenty-eight thin sections, eighteen from the Mitsue area and ten from the Nipisi area. Two hundred and fifty points per thin section, using a spacing of 0.4 mm, were identified and classified as: quartz, feldspar, rock fragments, cement, matrix, accessory minerals and pore space. Percentage results of these analyses are shown on Table IV. Feldspar was further subdivided into K-feldspar and plagioclase. Rock fragments were subdivided into two genetic types, and cement was identified as anhydrite, carbonate and silica cement.

All thin sections were etched with hydrofluoric acid fumes for thirty seconds and stained with a concentrated sodium cobaltinitrite solution (Hayes and Klugman, 1959). After this treatment K-feldspar stains yellow, whereas plagioclase appears milky white from the etching, and quartz is not affected. The etching process did not appear to have dissolved any of the other constituents of the thin section.

Essential Components

Essential components are mineral constituents of a sandstone which are necessary to its classification. The averages for the essential components of the Gilwood sandstone when recalculated to one hundred percent are: 77.8 percent quartz, 22.1 percent feldspar and less than 1 percent rock fragments for the Mitsue area; 67.6 percent quartz, 32.0 percent feldspar and less than 1 percent rock fragments for the Nipisi area.

a. Quartz

Commonly in petrographic studies of detrital rocks, quartz has been subdivided into several genetic varieties, which are differentiated on the basis of external morphology, internal morphology and extinction characteristics. Work by Blatt and Christie (1963) and Conolly (1965) has cast doubt on the universal validity of these genetic varieties. Blatt and Christie (1963) found that differences in the percentages of non-undulatory quartz (extinction less than one degree) between plutonic igneous rocks, schists and gneisses are not statistically significant. They also state that it is likely that large quantities of polycrystalline quartz are derived from both plutonic igneous and metamorphic rocks. Conolly (1965) reports that the amount of undulatory quartz (extinction greater than one degree) in a sandstone is affected by post-depositional diagenesis, folding and faulting, and that the percentage of undulatory quartz is dependent on the modal sand-size of the sandstone and increases with increase in grain size. The writer found that an increase in percentage of undulatory quartz with increasing grain size is true also of the samples of the Gilwood sandstone studied.

Because of these doubts cast on the recognition of genetic subdivisions of quartz, no attempt has been made to distinguish genetic groups. A survey was made of the percentages of non-undulatory quartz, undulatory quartz and polycrystalline quartz in the four samples that were used for the size analysis. Non-undulatory quartz, if restricted to Blatt and Christie's (1963) definition, makes up a very small percentage of the samples. If the definition of Folk (1964) for slightly undulose quartz is used (extinction of less than 5 degrees), then slightly undulose quartz varies from 14 to 52 percent. Undulatory quartz (extinction greater than 5 degrees) varies from 35 to 51 percent, and polycrystalline quartz ranges from 13 to 35 percent.

b. Feldspars

Several kinds of feldspar were observed, but most of it consists of potash varieties. Microcline and orthoclase appear to exist in approximately equal amounts. What appears to be perthite or anti-perthite was also observed in some thin sections.

There appears to be two groups of feldspars. The minor one consists of partially altered feldspar showing signs of having been weathered. The second group, which dominates, appears to be fairly fresh and unaltered.

c. Rock Fragments

Rock fragments make up only a very minor amount of the Gilwood sandstone. At Mitsue they constitute less than one half percent of the rock in the samples examined, whereas at Nipisi they make up slightly more than one percent of some samples. In the Mitsue area only shale fragments were found, whereas in the Nipisi area some diversity is shown because chert and igneous-metamorphic rock fragments were identified as well as shale fragments. The percentages of both feldspar and rock fragments are greater in the Nipisi area than in the Mitsue area. The implications of this will be discussed under environment of deposition because it probably has some bearing on this problem.

Matrix

Matrix is unevenly distributed throughout the Gilwood sandstone, making up from 0.4 to 16.8 percent of the rock volumetrically. Its composition is fairly consistent in all the samples studied and consists mainly of clay, mica, feldspar and quartz. Usually small dolomite rhombs are scattered throughout the matrix and make it very hard to distinguish matrix from badly deformed sedimentary rock fragments. In most cases, a high percentage of matrix is associated with a low percentage of cement. Some of the matrix may have been replaced by both carbonate and anhydrite cement. (Plate V-3).

Cements

Volumetrically, cement is an important constituent of most of the samples studied, constituting from 3.2 to 32 percent of the total rock. Three types of cement were observed: anhydrite, carbonate and silica.

a. Anhydrite Cement --

In all samples, except two, anhydrite is the most important intergranular cement. It is easily recognized by its rectangular pseudocubic cleavage, bright interference colors and positive biaxial interference figure. Most of the anhydrite occurs in the coarser grained rocks, where it appears to have replaced both carbonate cement and matrix (Plate IV-8, V-1,3), and was probably the last cement to be precipitated.

b. Carbonate Cement --

There is no way to distinguish calcite from dolomite in thin section without staining. Since the thin sections used in this study were stained for K-feldspar, it was felt that it would not be wise to stain the thin sections again for calcite and dolomite. Most of the carbonate cement, however, is probably dolomite because of the euhedral crystal shape plus the fact that calcite is very minor in the mudstones while dolomite is abundant. The amount of carbonate cement varies from 0 to 15 percent.

Carbonate cement was found replacing feldspar (Plate V-1,2), quartz grains (Plate IV-5,6,7) and silica cement (Plate IV-5). It also replaces matrix, as evidenced by small carbonate rhombs in most of the matrix. This replacement may have been extensive in areas where no matrix exists at the present.

c. Silica Cement --

Silica cement is present in all samples which were studied. It occurs as overgrowths in optical continuity with detrital quartz grains (Plate IV-4,5,6,8). Quartz

overgrowths were distinguished from the nucleus detrital grain by one or more of the following criteria (Lerbekmo, 1961): a thin line of impurities marks the boundary between the detrital grain and the authigenic overgrowth (Plate IV-4);the detrital grain shows straining or undulatory extinction whereas the overgrowth does not; the nucleus has inclusions while the overgrowth has relatively few or none (Plate IV-5).

Silica overgrowths and cement vary from 2.0 to 14 percent volumetrically and show both irregular shape (Plate IV-4) and well-developed crystal faces (Plate IV-5,6).

Accessory Minerals

The accessory minerals found in the Gilwood sandstone are: mica, chlorite, collophane (including organic remains), zircon and garnet, but no single thin section contains all of these accessory minerals. At this point it must be mentioned that sometimes accessory minerals are present in thin sections but in quantities too small to be recorded by the number of points counted. This is especially true if the mineral makes up less than one percent of the volumetric composition. To correct this error, a P is shown on Table IV if an accessory mineral is present in that thin section, but was not counted.

Volumetrically, the accessory minerals are not an important group, except in samples 125, 131, and 133, where mica makes up a notable (7.2 to 10.4) percentage of the rock. Zircon, where it was observed, is usually present as scattered grains in a thin layer, being the only accessory mineral to occur in this way.

Pore Space

Since pore space is quantitatively important in some of the samples, and its distribution is of economic importance, it was counted when it could definitely be identified as such. In some cases porosity could not be distinguished from holes produced in the making of the thin section. In doubtful cases it was not counted as porosity, and in one sample (#225), it was found impossible to determine porosity. Volumetrically, porosity ranges from 0 to 16 percent with an average of 4.4 percent.

Porosity distribution appears irregular in most samples because of the large amount of cement that is usually present. In general, it can be stated that the porosity is better in the finer grained sandstones than the coarser grained ones, because of the larger amount of cement present in the coarser grained rocks.

Classification

A considerable number of sandstone classifications have been proposed in recent literature. Klein (1963) and McBride (1963) have reviewed the majority of these. Criteria used in sandstone classifications include:

> "composition (indication provenance), diastrophism, mineralogical maturity, textural maturity (sorting index), fluidity factor (fluid viscosity and density) and primary structures." (Klein, 1963).

For the purpose of the present study, a compositional classification has been found to be most useful, and the classification scheme proposed by Travis (1955) has been adopted.

Figure 5 shows the proportions of essential components recalculated to 100 percent for each sample. According to the Travis classification, thirteen of the eighteen samples from the Mitsue area are feldspathic sandstones, whereas the remaining five are arkoses. Of the ten samples from the Nipisi area, eight are definite arkoses and two are transitional between arkose and feldspathic sandstone.

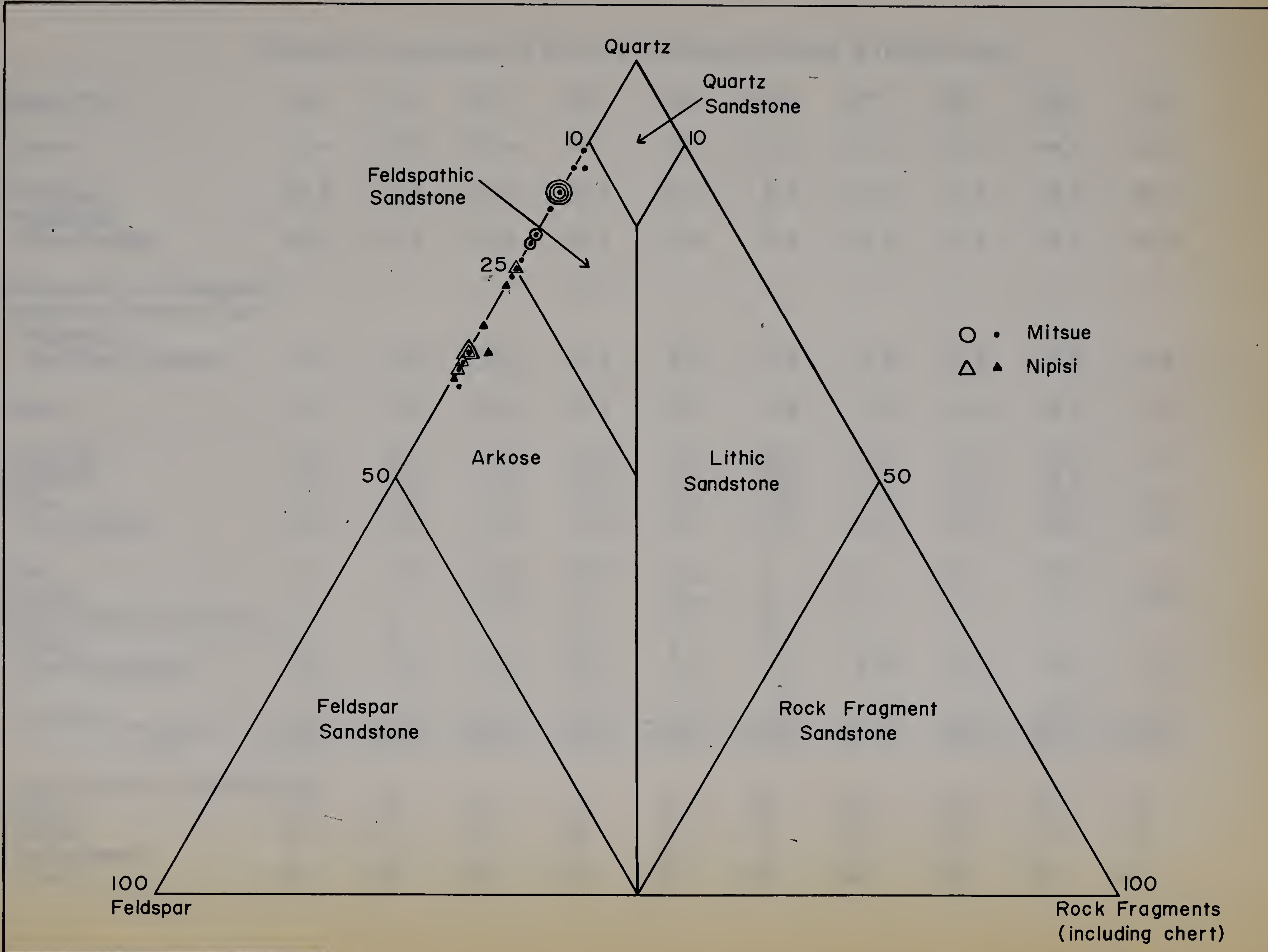


Figure 5. Compositional Classification of Gilwood Sandstone. (Triangular Diagram after Travis, 1955)

Table IV-1 Composition of Gilwood Sandstone in volume % (Mitsue area)

Sample No.	122	124	125	131	133	136	179	181	182	183
Quartz	58.4	60.8	40.4	46.0	49.6	68.0	69.2	62.4	64.4	47.2
K-feldspar	20.8	16.4	23.6	28.4	26.8	8.4	10.0	17.6	18.8	26.4
Plagioclase	-	-	-	-	-	-	-	-	-	-
Total Feldspar	20.8	16.4	23.6	28.4	26.8	8.4	10.0	17.6	18.8	26.4
Sedimentary rock fragments	-	-	-	0.4	-	-	-	-	-	-
Igneous-metamorphic rock fragments	-	-	-	-	-	-	-	-	-	-
Total Rock Fragments	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Matrix	7.2	2.0	16.8	10.4	12.4	0.8	1.6	6.0	3.6	6.4
Anhydrite	6.4	9.2	1.6	0.4	0.4	18.0	16.4	5.2	0.4	1.2
Carbonate	1.2	0.4	0.4	0.4	0.4	0.8	-	-	0.4	-
Silica	4.4	7.6	7.2	3.6	2.4	3.6	2.8	4.0	7.6	5.6
Total Cement	12.0	17.2	9.2	4.4	3.2	22.4	19.2	9.2	8.4	6.8
Mica	P	2.0	7.2	10.4	7.2	-	-	P	0.8	1.2
Chlorite	-	-	0.8	-	0.4	-	-	-	P	0.8
Org. remains & collophane	P	-	-	P	P	0.4	-	-	-	-
Zircon	P	P	-	P	P	P	-	-	-	-
Total Accessories	0.0	2.0	8.0	10.4	7.6	0.4	0.0	0.0	0.8	2.0
Pore space	1.6	1.6	2.0	0.0	0.4	0.0	0.0	4.8	8.0	11.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for classification:										
Quartz	74	79	63	61	65	89	87	78	76	64
Feldspar	26	21	37	38	35	11	13	22	24	36
Rock fragments	-	-	-	1	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100	100	100

Table IV -2, Composition of Gilwood Sandstone in Volume % (Mitsue area)

Sample No.	184	185	186	204	210	221	224	225
Quartz	56.8	59.2	62.4	50.8	60.4	62.0	58.4	61.6
K-feldspar	15.6	8.4	14.0	13.2	11.6	11.6	10.8	12.0
Plagioclase	-	-	-	-	-	-	-	-
Total Feldspar	15.6	8.4	14.0	13.2	11.6	11.6	10.8	12.0
Sedimentary rock fragments	-	0.4	-	-	-	-	-	-
Igneous-metamorphic rock fragments	-	-	-	-	-	-	-	-
Total Rock Fragments	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Matrix	13.6	2.0	1.6	2.0	1.2	1.2	7.2	0.4
Anhydrite	2.8	7.6	3.2	20.8	18.0	11.6	12.4	21.2
Carbonate	2.8	-	-	-	-	3.6	-	-
Silica	4.8	6.4	4.4	11.2	4.0	2.0	4.4	4.8
Total Cement	10.4	14.0	7.6	32.0	22.0	17.2	16.8	26.0
Mica	0.4	-	0.4	-	P	P	-	-
Chlorite	P	-	0.4	-	P	-	P	-
Org. remains & collophane	-	-	-	P	2.8	-	P	-
Zircon	-	-	1.2	1.2	-	3.2	-	-
Total Accessories	0.4	0.0	2.0	1.2	2.8	3.2	0.0	0.0
Pore space	3.2	16.0	12.4	0.8	2.0	5.6	6.4	N.C.
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for classification:								
Quartz	78	87	82	79	84	84	84	84
Feldspar	22	12	18	21	16	16	16	16
Rock fragments	-	1	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100

Table IV-3, Composition of Gilwood Sandstone in Volume % (Nipisi area)

Sample No.	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10
Quartz	47.2	52.8	48.0	45.6	46.8	54.0	47.2	55.2	46.0	55.6
K-feldspar	28.8	25.2	25.6	25.6	24.0	19.6	25.6	17.2	22.8	18.8
Plagioclase	-	-	-	0.8	-	-	0.4	1.2	0.4	-
Total Feldspar	28.8	25.2	25.6	26.4	24.0	19.6	26.0	18.4	23.2	18.8
Sedimentary rock fragments	-	-	-	-	1.2	-	-	-	0.8	-
Igneous-metamorphic rock fragments	-	-	-	-	-	-	-	-	0.4	-
Total Rock Fragments	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	1.2	0.0
Matrix	1.2	8.8	7.2	0.4	4.8	1.2	4.4	4.0	10.4	1.6
Anhydrite	2.8	0.4	0.4	16.8	5.2	2.4	4.4	2.8	2.0	4.8
Carbonate	14.8	0.8	0.4	6.0	0.4	10.0	2.8	1.6	1.2	4.0
Silica	4.8	5.2	7.6	3.2	11.2	10.0	5.6	11.2	12.8	13.6
Total Cements	22.4	6.4	8.4	26.0	16.8	22.4	12.8	15.6	16.0	22.4
Mica	-	0.4	2.4	0.8	-	P	-	1.2	P	-
Chlorite	-	-	-	P	-	-	-	0.4	-	P
Org. remains & collophane	P	0.8	P	-	0.4	-	P	P	-	-
Zircon	P	0.4	P	P	-	-	-	-	P	P
Garnet	P	P	-	-	P	-	P	-	0.4	-
Total Accessories	0.0	1.6	2.4	0.8	0.4	0.0	0.0	1.6	0.4	0.0
Pore Space	0.4	5.2	8.4	0.8	6.0	2.8	8.8	5.2	2.8	1.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for Classification:										
Quartz	62	68	65	63	65	73	64	75	65	75
Feldspar	38	32	35	37	33	27	36	25	33	25
Rock fragments	-	-	-	-	2	-	-	-	2	-
Total	100	100	100	100	100	100	100	100	100	100

MINERALOGY OF THE MUDSTONES

Introduction

Ten representative samples were chosen from one well in order to determine the mineralogy of the mudstones in the Watt Mountain Formation. The 4-4-73-4W5 well was used for this purpose because the section encountered in this well contains a large proportion of mudstones. Sample depths are shown on Figure 2 and given in Appendix B.

Techniques

Each sample was crushed using a Bleuler rotary mill, and the resulting powder was used for X-ray work. Two types of mounts were used for each sample. A briquet was prepared by pressing approximately 1 gram of the powder with a cellulose backing, at a pressure of 20,000 p.s.i.. The second mount was of the clay-size fraction of each sample sedimented onto a glass slide.

To prepare the oriented glass slide mount, the samples were treated as follows. About ten grams of the powder were mixed with 0.1 gram of Calgon and 500 cc. of distilled water in a rotary blender for five minutes in order to disperse the clay minerals. The resulting suspension was then allowed to settle under gravity for four and one half hours. A 50 cc. sample was taken out, by means of pipette, at a depth of 5 cm. below the surface. Such a sample should contain only the less than 2 micron fraction (Folk, 1964). The 50 cc. aliquot was then allowed to settle under gravity onto a frosted glass slide for about 22 to 24 hours, in order to collect the 2 micron down to 1/2 micron fraction on the slide. The remaining suspension was siphoned off and the slide allowed to dry at room temperature.

A Phillips Norelco Type 12045 B/3 X-ray diffractometer with a geiger counter, using nickel filtered Cu K alpha radiation operated at 35 KV and 15 MA, was used throughout the study for all samples. A scalar rate-meter with a setting

of 4-1-4 was used at all times. The diffractograms were recorded on a Brown strip chart recorder, running at a speed of one half inch per minute. The briquet mounts were used to determine the gross mineralogy and were scanned over the 2θ range 0 to 60 degrees at a rate of one degree 2θ per minute. The scan interval includes the principal peaks of all the minerals that would be expected to be present. The oriented samples were scanned several times. A first scan was made from 0 to 50 degrees 2θ, at a rate of one degree per minute. This was followed by a slow run (one-eight of a degree 2θ per minute) from 24 to 27 degrees 2θ to achieve optimum separation of the chlorite 3.54Å peak and the kaolinite 3.58Å peak (Biscaye, 1964). The slides were then placed above ethylene glycol in a vacuum for 12 hours, and another fast scan was made from 4 to 13 degrees 2θ to test for the presence of expandable clays. Following this, the samples were heated at 500°C for 12 hours (Warshaw and Roy, 1961) to aid in the distinction between chlorite and kaolinite. Finally, one gram of clay sized material (2 to 1/2 microns) was prepared for each of three of the samples, using the same technique as above. This was used to make differential thermal analysis traces, which were run at a speed of 16°C per minute to 1050°C.

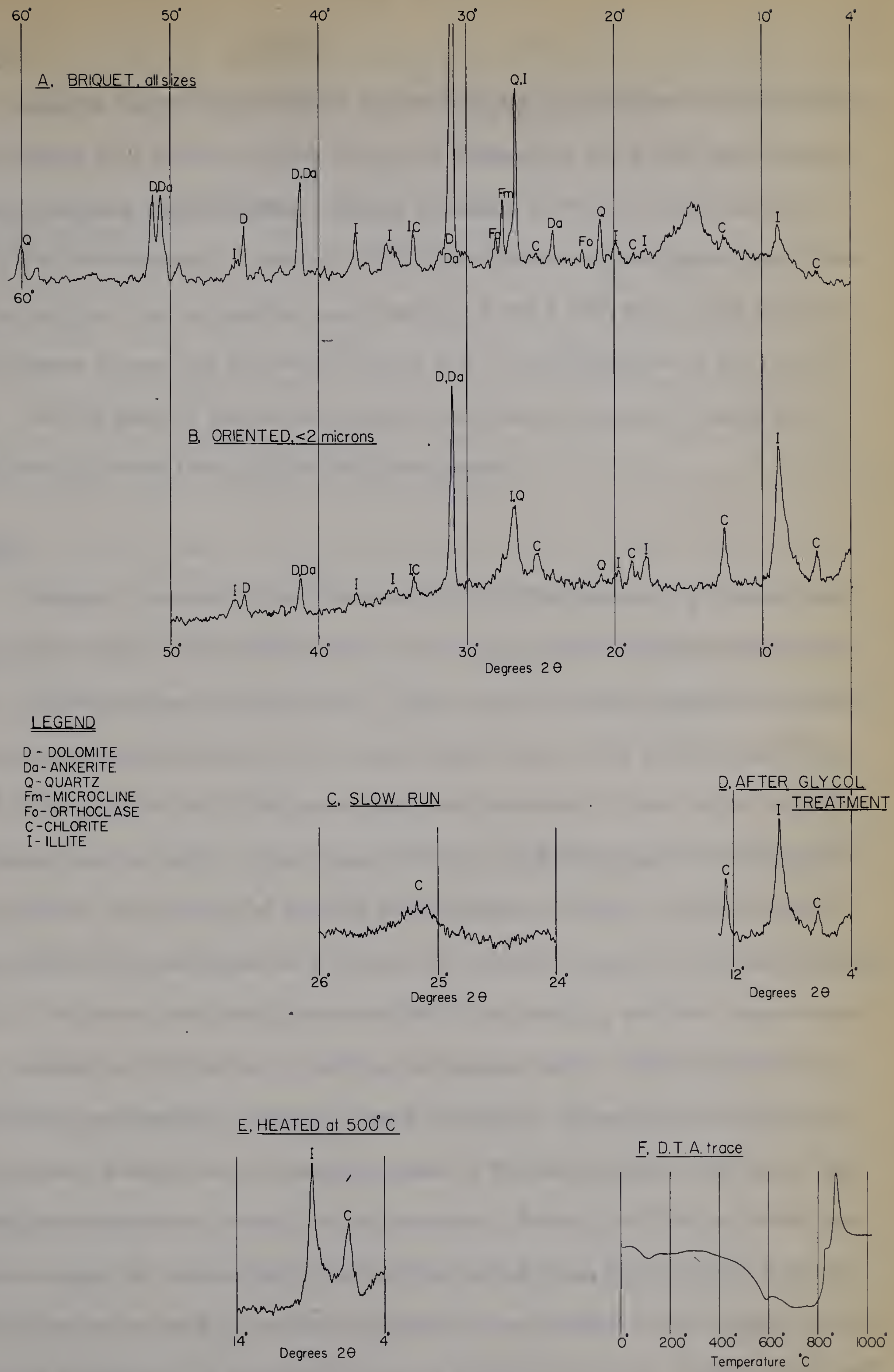
All samples were analyzed for dolomite and calcite content using the quantitative gasometric method employing the Chittick apparatus. Dreimanis (1962) gives a detailed description of the method used and states that:

> "with reasonable care and taking large samples of 1.700 or 0.850 gm. the percentages of carbonates as determined by the method described in this paper should have a probable error of not more than $\pm$ 0.3 in most cases". (Dreimanis, 1962, p. 525).

X-ray Mineral Identification

The minerals identified from the diffractograms of the briquets and oriented samples are discussed below. Figure 6 shows the diffractometer and D.T.A. traces for one sample (#274), which is fairly typical of all the samples.

SAMPLE 274



X-RAY DIFFRACTOMETER & D.T.A. TRACES

Figure 6

Quartz

Because the principal peak of quartz at 3.34Å is coincident with the moderately strong 3.32Å diffraction from illite, the presence of the 4.26Å peak was used to make a positive identification. Quartz is present in the clay-size fraction as well as the coarser sizes. It appears to be more abundant in the coarser grain-size fraction judging from the greater peak intensity of the 4.26Å peak in the briquet diffractometer traces, but this may be partly due to the differences in the type of mount. On the basis of limited petrographic examination, quartz is found to be present mainly in the form of silt-size clastic grains.

Feldspar

Feldspar is present in small amounts in all of the samples. It is recognized by the combination of the 3.25Å peak of microcline and the 3.18Å peak for orthoclase. No plagioclase was identified. Table V gives the total feldspar (microcline plus orthoclase) peak height to quartz peak height ratios. The contribution of the 3.32Å illite peak to the 3.34Å quartz peak was subtracted in order to get only the contribution due to quartz. The intensity of the 3.32Å illite peak was obtained by taking 90% of the intensity of the 10Å peak (Brindley, 1961a). The use of peak heights rather than peak areas as a measure of intensity is open to criticism (Brindley 1961b). Peak areas more nearly represent the true intensity, and their measurement is less affected by difficulties in defining background level. The simplification of peak height measurements, however, seems justifiable, because any interpretation of these ratios is based on the changing values of the peak height ratios rather than the absolute quantitative value. As can be seen in Table V, all the ratios are less than one except for samples 262, 263 and 264, which have ratios greater than one. The feldspar-quartz peak ratios that are less than one conform to the feldspar-quartz ratios from sandstone thin sections which vary from 0.12 to 0.62. Samples 262, 263 and 264 appear, therefore, to be anomalous. They are all part of one extensive

mudstone unit (5B) which is present throughout the Mitsue area. The implication of these apparently anomalous ratios will be discussed under environment of deposition because it has some bearing on this problem.

Carbonate Minerals

Dolomite was recognized on all the diffractometer traces by its principal peak at 2.89Å. Since the peak height varied greatly from sample to sample, quantitative carbonate analysis was done on each sample using the Chittick apparatus (Dreimanis, 1962), the results of which are shown on Table VI. Each sample was analyzed at least twice and the values shown in Table VI are averages for each sample. It was found that the error involved was comparable to that reported by Dreimanis. In the present study it varied from 0.05 to 0.4 percentage units for dolomite and 0.05 to 0.2 for calcite for all samples except sample 274 which gave a variation of 2.9 for calcite and 3.6 for dolomite. This large absolute error appears to be due to the large amount of dolomite present. Table VI also shows the diffraction peak heights of the 2.19Å dolomite peak. This peak was used rather than the stronger 2.89Å peak because the latter in samples with a large dolomite content went off scale. As can be seen, the relative values of the peak heights correspond closely with the percentage dolomite. Study of several thin sections shows that the dolomite exists in the form of euhedral rhombs. (Plate IV-3).

In addition to dolomite, another carbonate mineral, ankerite or ferroan dolomite, was identified on all the diffraction traces. It is characterized by a weak peak at 3.7Å. This is the only peak which allows ankerite to be distinguished from dolomite, since all the other spacings are nearly coincident with those of dolomite. Ankerite has the same structure as dolomite and the only difference is that in ankerite, ferrous iron and manganese have substituted for part of the magnesium in dolomite. Nealy all dolomites contain a small amount of ferrous iron (Deer et al., 1966, p. 489) and solid solution exists between the two species.

Since both minerals have approximately the same solubility in hydrochloric acid, ankerite is probably included in the percentage of dolomite given in Table VI.

Calcite was not identified from the diffractometer traces. It is, however, present in minor amounts which are too small to be noticed on the diffractograms. No other carbonate minerals could be identified.

Illite

Illite is present in all samples and is characterized by peaks due to basal spacings of 9.9 to 10Å, 4.9Å, 3.3Å, 2.49Å and 1.99Å (Bradley and Grim, 1961). As used here, the mineral illite encompasses the broadest definition of that term for "those of the clay mineral constituents of argillaceous sediments belonging to the mica group" (Bradley and Grim, 1961, p. 222). No identification of the various species such as glauconite, hydromuscovite, muscovite, sericite, etc. was made. However, it is suggested that glauconite, mica and muscovite make up at least part of the illite diffraction, because these minerals were identified through the binocular microscope.

Illite is the major clay mineral present in the mudstones. This can readily be seen from Table V, where the ratios of the chlorite 7Å peak height to the illite 10Å peak height and the parts of chlorite per one part illite (Johns, et al., 1954) are shown. Only one sample #273, has more chlorite than illite.

Chlorite

The identification of chlorite in this study requires some explanation. On all diffractograms a strong 7Å peak was accompanied by a weak to a fairly strong 14Å peak. The 14Å peak at about 6° 2θ on Figure 6B is one of the strongest given by any of the ten samples. The 7Å peak, at 12.6° 2θ could be due to either kaolinite or an iron-rich chlorite.

Warshaw and Roy (1961) and Biscaye (1964) have discussed the difficulty of

distinguishing kaolinite from chlorite. Biscaye (1964) recommends a slow scan over the 3.5Å peak in order to separate the 3.58Å kaolinite and 3.54Å chlorite peaks. This was done for all samples, and as can be seen in Figure 6, there is no clear split in the peak. Thus the result is indeterminate. There is, however, a tendency towards the smaller spacing of the 3.54Å chlorite peak. Warshaw and Roy (1964) recommend heat treatment at 500°C for 12 hours. For chlorites this should result in a broad peak at 13 to 14Å, accompanied by a decrease in the intensity of the other basal spacings. Kaolinite will lose all basal diffractions when treated in this manner. This treatment was applied to all samples and resulted in an increase in intensity of the weak 14Å peaks, while some of the other 14Å peaks were not affected; it was also accompanied by loss of all other basal spacings. The presence of chlorite was thus confirmed, but the question still remains whether or not kaolinite is present.

In another attempt to solve this problem, three samples (#258-259, #267, and #274) were subjected to differential thermal analysis. None of the traces showed the characteristic exothermic peak of kaolinite between 900° and 1000°C (Grim, 1953), thus suggesting that kaolinite is not present in appreciable amounts. The traces are similar to the ones shown by Bradley and Grim (1961, p. 227) from samples in which there was illite with associated chlorite.

Since none of the techniques employed definitely pointed to the presence of kaolinite, it is concluded that the principal minerals contributing to the 7Å peak is chlorite. The presence of minor amounts of kaolinite, however, remains a possibility.

Other Minerals

Most of the samples contain small amounts of anhydrite. This was recognized by a minor peak at 3.49Å. Since this peak is nearly coincident with the 3.5Å chlorite peak, it could not be identified on most of the oriented mounts.

Only one sample (#273) showed pyrite. This was recognized by the principal diffraction of pyrite at 1.63Å (Brown, 1961). Sample 273 differs in other aspects also. Of all the samples analysed it is most nearly a shale as it possesses some fissility and contains very little silt-size material. It is the only sample in which chlorite appears to exist in larger quantities than illite, and it contains no appreciable carbonates, even though it is partially interbedded with dolomite.

Other mineral may be present in minor amounts in the mudstones, but none can be recognized from X-ray diffraction traces or seen in thin section.

Significance of Color

The color of the mudstones varies from greenish gray, with or without brown mottling, to completely grayish brown or dusky brown. To determine whether this might be due to variations in total iron content, X-ray fluorescence spectography was used to analyse the samples for total iron content, reported as weight percent Fe_2O_3.

The procedure described by Pelzer (1965) was followed in this study, the only modification being that a Cr source was used instead of a W source. A Phillips Norelco Type 12215/0 unit with a LiF analyzing crystal was used to make the analytical determinations. A scintiliation counter was used to get the number of counts for 10 seconds both on the top of the iron peak (57.62 degrees 2θ) and at the background position (56.50 degrees 2θ). Three readings were taken at the peak and background positions for each sample and the average background reading subtracted from the average peak reading to give the count for total iron. Three analyzed standards were used to determine the slope of the calibration curve, which is shown on Figure 7. The three standards used in this study were analyzed in the rock analysis laboratories at the University of Alberta, and the weight percent Fe_2O_3 of each of these is shown on Table VII. Table VII also shows the color, counts per second above background and the weight percent Fe_2O_3 of each of the unknowns. Sample

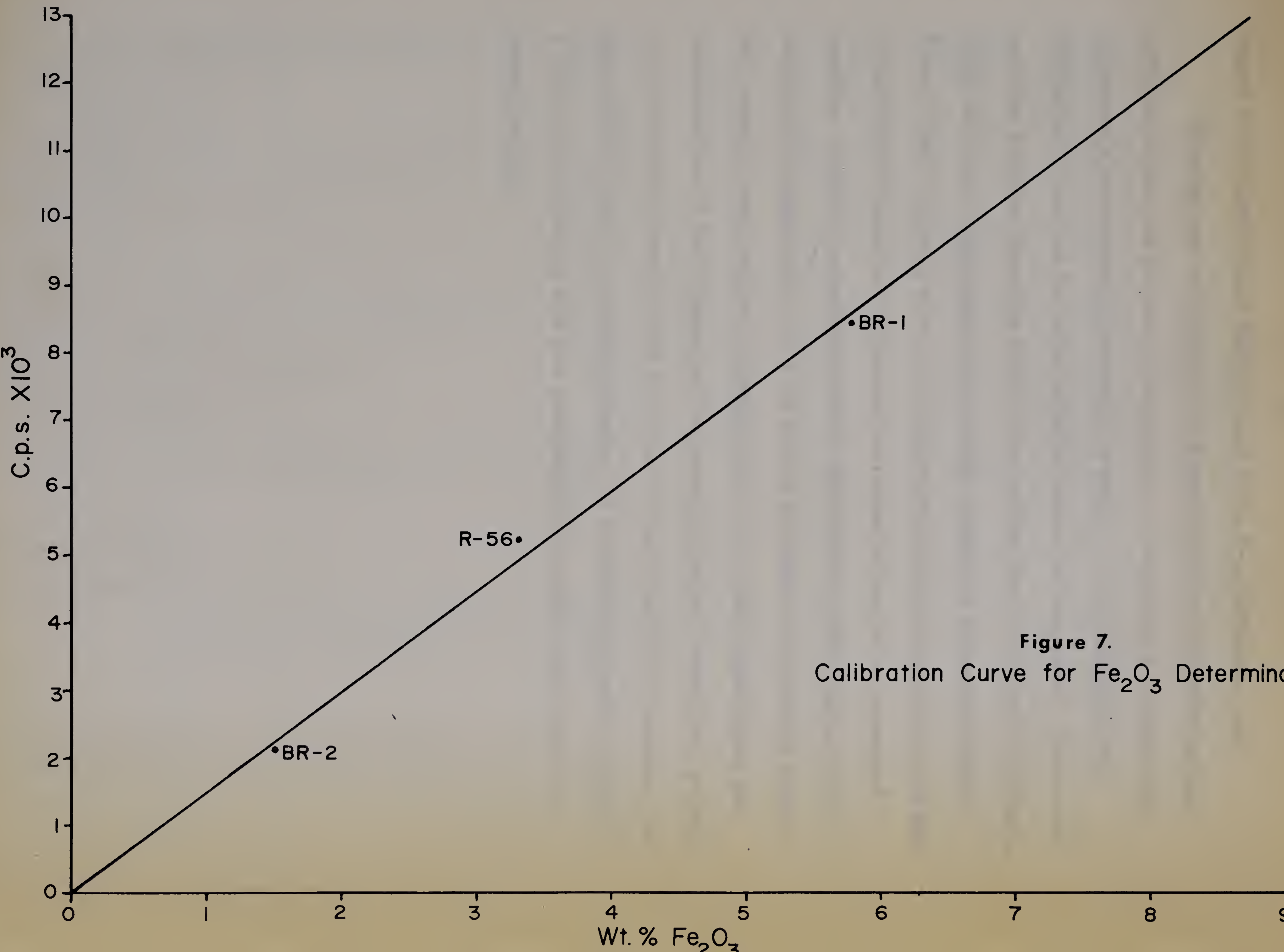
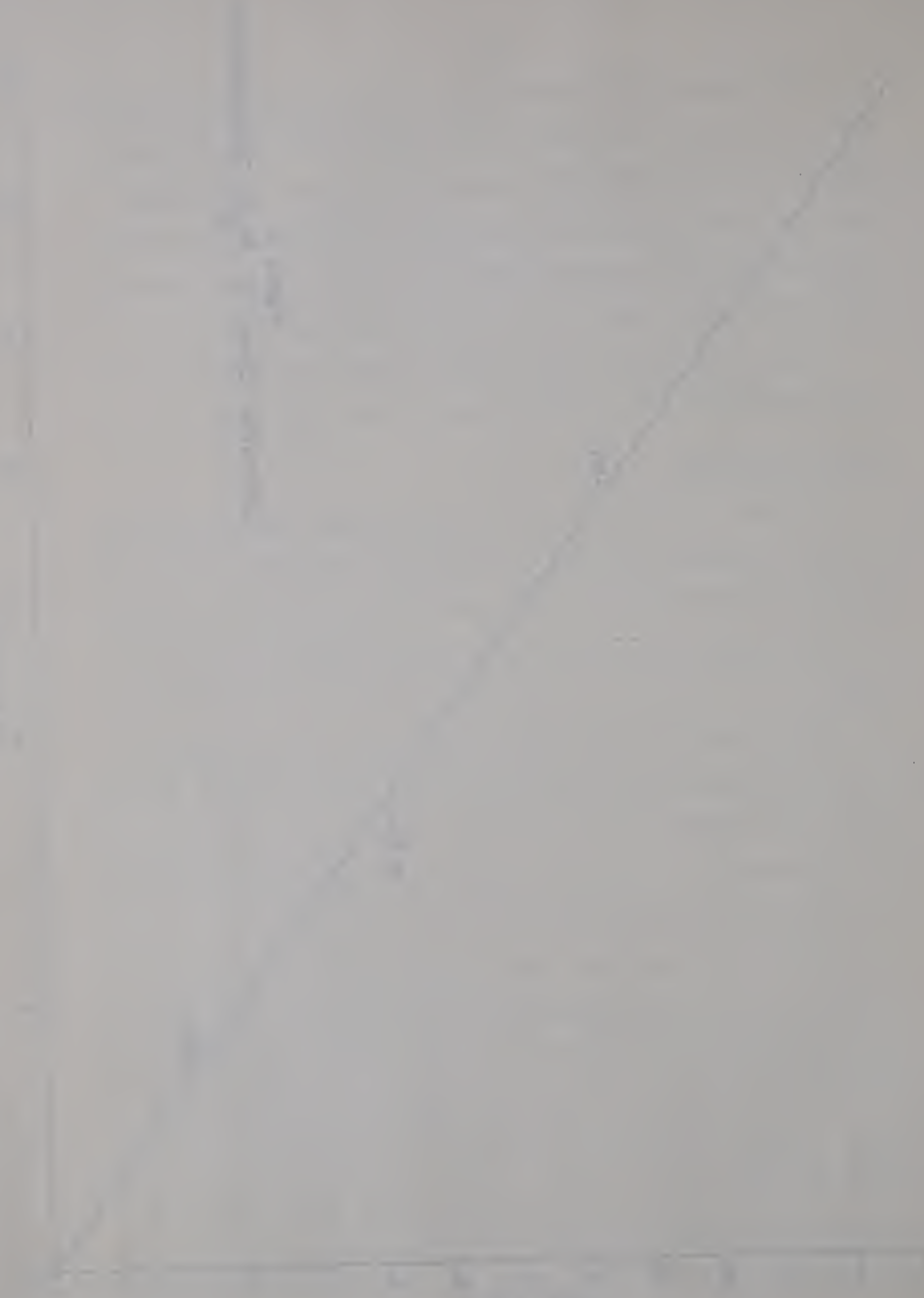


Figure 7.
Calibration Curve for Fe_2O_3 Determinations.



mounts are the same briquets that were used in the X-ray diffraction work.

As can be seen on Table VII, there appears to be no correlation between total iron content and the color of the mudstones. Since there is no appreciable difference in the mineralogy from sample to sample, it is concluded that the differences in color are due to the oxidation state of the iron present. Brown colors would be due to an abundance of ferric iron, and the green color due to the absence of the ferric iron. This appears to be a similar situation to that encountered by Friend (1966) in his study of the clay fractions and colors of some Devonian red beds in the Catskill Mountains. In his case, the redness was due to the presence of hematite. However, no hematite could be identified from diffractograms or thin sections in the present study. It is felt that the discoloration and mottling is probably caused by small amounts of hematite which is very finely disseminated, and amorphous forms of ferric hydroxide. The source for the ferric hydroxide is probably iron-rich detrital minerals, which may occur in minor amounts in the mudstone, and thus would not show up on the diffractograms. It is possible that partial oxidation of iron-rich chlorites may also have contributed to the color, either directly or through leaching.

TABLE V

XRD PEAK HEIGHT RATIOS

Sample Number	258 259	262	263	264	266	267	268	269 270	273	274
$\frac{\text{Fd.}}{\text{Qtz.}}$	0.38	2.3	1.0	1.3	0.48	0.38	0.18	0.47	0.74	0.52
$\frac{\text{Chlor.}}{\text{Ill.}}$	0.61	0.38	0.40	0.50	0.36	0.28	0.23	0.31	1.04	0.44
Parts chlor. per one part ill.	0.36	0.26	0.29	0.38	0.25	0.02	0.17	0.02	1.05	0.02

TABLE VI

CARBONATE ANALYSIS RESULTS

Sample Number	% dolomite	% calcite	total % carbonates	$\frac{\text{dolomite}}{\text{calcite}}$	2.19Å peak heights
258-259	16.4	1.3	17.7	12.7	0.8"
262	20.6	0.5	21.1	41.2	1.0"
263	16.0	0.5	16.5	32.0	0.6"
264	1.8	0.7	2.5	2.57	N.P.
266	1.3	0.7	2.0	1.86	N.P.
267	13.8	0.9	14.7	15.3	0.9"
268	35.8	1.8	37.6	19.9	1.5"
269-270	19.1	1.4	20.5	13.6	1.0"
273	1.0	0.7	1.7	1.43	N.P.
274	40.6	5.7	46.3	7.12	3.1"

N.P. - no peak present

TABLE VII

MUDSTONE COLOR AND Fe_2O_3 DETERMINATION DATA

Sample Number	Color	C.p.s.	Wt.% Fe_2O_3
258-259	dk. greenish gray	9,673	6.52
262	dk. greenish gray	12,440	8.37
263	dusky brown	9,293	6.26
264	lt. greenish black	12,001	8.08
266	dk. greenish gray	10,639	7.16
267	moderate brown	10,126	6.82
268	grayish brown	8,700	5.86
269-270	greenish gray with dusky brown mottling	9,878	6.65
273	lt. greenish black	9,048	6.10
274	brownish gray with v. dusky red mottling	5,920	4.00
Standards			
BR-1 (R-66)		8,432	5.77
BR-2 (R-67)		2,146	1.50
R-56		5,232	3.30

SUMMARY AND CONCLUSIONS

The composition of the Gilwood Sandstone can be summarized as follows:

Color	-Pale yellowish gray to light gray.
Grain size	-Fine to coarse grained (up to granule size locally.)
Angularity	-Angular to rounded.
Sorting	-Moderately well to poor.
Textural Maturity (Folk, 1951)	-Submature to mature.
Feldspar	-8 to 28%, increasing to the north-west, K-feldspar most common.
Rock fragments	-Less than 1%.
Cement	-Silica, carbonate and anhydrite (3.2 to 32%).
Accessories	-Mica, chlorite, collophane, zircon and garnet.
Porosity	-0 to 16%, depending on cement distribution.
Classification	-Mainly feldspathic sandstone in the Mitsue area and arkose in the Nipisi area.

The mineralogy of the mudstones in the Watt Mountain Formation is relatively simple. It consists mainly of quartz, dolomite (plus ankerite), feldspar, illite and chlorite, with minor amounts of anhydrite and calcite. The dolomite appears to exist entirely in the form of rhombohedrons. The brown discoloration and mottling of the green mudstones is apparently due to ferric oxide staining.

Provenance

The composition of a sediment is controlled by the composition, climate and relief of the source area. The virtual absence of sedimentary rock fragments and abundance of feldspar in the Gilwood sandstone indicates that it was probably derived from an igneous-metamorphic terrain. The only such terrain which existed

in the immediate vicinity was the Peace River High. This has been accepted as the source area by most geologists in Western Canada, and the present study did not find any evidence to the contrary. According to Burwash (1957) and Burwash et al., (1964) the Peace River High is composed mainly of pelitic and quartzo-feldspathic metamorphic rocks and acid to intermediate igneous rocks, with only minor amounts of sedimentary, meta-sedimentary, volcanic, meta-volcanic and basic igneous or metamorphic rocks (total of nine percent). There is no problem in deriving a sandstone with the composition of the Gilwood Sandstone from a source area made up of the above rock types. Since most of these rocks are medium to coarse-grained, no large amount of igneous-metamorphic rock fragments would be expected. Some of the quartz grains in the Gilwood sandstone are well rounded and appear to be second-cycle quartz. These are minor and may be explained by the existence of some pre-Middle Devonian sedimentary rocks on the Peace River High, perhaps continental in origin. The small amount of weathered feldspar grains in the sandstone may also be second cycle. That the Peace River High is the source area is also indicated by the regional distribution of the Gilwood Sandstone, which occurs as a fringe around the High (Grayston, et al., 1964; Suska, 1963).

The presence of a large amount of relatively fresh angular potash feldspar indicates that there was little time for weathering at either the source or at the site of deposition. This suggests that the relief on the Peace River High was fairly great and that erosion and deposition of the sediment was rapid. Faulting has been shown to have taken place on the Peace River High in pre-Middle Devonian times and later during the Paleozoic (Sikabonyi, 1959; de Mille, 1958). It is suggested here that faulting took place on the Peace River High during Watt Mountain time to give rise to the extensive sand developments both on the south-east side (Gilwood sandstone) and the north-west side (Manning sandstone). It

is felt that a general uplift of the Peace River Arch and the surrounding area (i.e., the Elk Point basin) would not be sufficient to create a landscape that could suddenly supply enough of the relatively fresh coarse clastic debris for the Gilwood and Manning sandstones. A slight uplift of the depositional basin may have occurred, but there is no indication of pronounced regression of the shoreline around the Peace River landmass at this time and it is felt that this was not the primary contributory factor.

Environment of Deposition

The Watt Mountain Formation was preceded by the restricted evaporitic conditions of the Muskeg Formation and succeeded by the more normal marine environment of the Slave Point Formation. It is the opinion of the writer that tectonic conditions in the depositional basin remained relatively stable and that deposition of the Watt Mountain Formation and the associated sandstones was primarily due to uplift (probably by faulting) in the source area. The Peace River High was contributing clastics to the evaporitic basin throughout Middle Devonian time (Basal Red Beds, Assineau Sandstone and Granite Wash). However, the Gilwood Sandstone extends farther out into the basin, overlapping the previous sediments, whereas the Basal Red Beds and Granite Wash are more nearly basal deposits. This is a clear indication that something happened on the Peace River High rather than in the basin. These conclusions are for the area of study and may not apply in other parts of the Elk Point basin and north of the Peace River High.

Figures 8 and 9 show that the Watt Mountain onlaps onto the Peace River High in the northwest portion of the area of study, but does not cover it. Since no evidence was discovered during this study to suggest an unconformity either at the top of, or in, the Watt Mountain Formation, it is felt that this is a depositional rather than an erosional feature.

Faunal evidence seems to point to fresh and brackish water conditions at

the time of deposition. Cyzica has been found abundantly in Pennsylvanian and Permian fresh and brackish water deposits and Pleistocene fresh water clays (Moore, et al., 1952). The charophytes, "constitute a small group of non-marine green algae that live entirely submerged in lakes and slow-moving bodies of fresh or brackish water....which afford a sandy or muddy bottom rich in humus....and they are found mostly in shallow waters ranging from a few centimeters to 5 meters." (Peck and Morales, 1966). The relative abundance of fresh to brackish water fish remains suggests at least near-shore conditions if not fresh water. The presence of these restricted fresh to brackish water faunas does not prove fresh or brackish water conditions for the Watt Mountain Formation, but is highly suggestive and at the very least, combined with the absence of marine fauna, indicates that fresh or brackish water was debouching nearby.

Sedimentary structures found in the Watt Mountain Formation suggest that deposition was in relatively shallow water and that some of the sediments were reworked quite extensively. Ferric oxide staining of the mudstones requires an oxidizing environment, and a ready explanation for this is sub-aerial exposure of the mudstones before burial. Friend (1966) found this to be true for the discoloration of the shales in cyclothems of the Catskill delta, where the oxidation of iron occurred in overbank deposits of an alluvial sequence. Since there is no indication that the Watt Mountain was deposited in deep water it is assumed that the iron oxide staining is due to sub-aerial exposure.

The dolomite member of the Watt Mountain Formation was probably deposited as a limestone and later dolomitized. The similarity in succession observed in the area of study with that of Saskatchewan leads the author to suggest that the dolomite unit of the Watt Mountain Formation in the area of study may be equivalent to the Dawson Bay Formation, and that the dolomitic mudstone below the dolomite unit is equivalent to the Second Red Beds. This is a similar proposal to that shown by Macauley (1964)

on his correlation chart. The limit of correlatable Dawson Bay shown by Grayston et al., (1964) is very near the study area and the present suggestion would thus extend this limit slightly farther to the northwest. The reason for suggesting this correlation is that the Dawson Bay was deposited under normal marine conditions (Kent, 1964), and no evidence for evaporitic conditions can be seen in the Watt Mountain. According to Kent (1964), there was a separation of the Elk Point basin at this time into two sub-basins separated by a shelf covered with shallow water. Normal marine conditions existed in the southern sub-basin and evaporitic conditions north of the shelf. Kent suggests that normal salinity of the sea water in the southern basin was maintained by a continuous influx of marine surface waters from the northwest over this shelf. Green (1958) shows a high trend on his map extending from the Peace River High across the location of the Elk Point basin towards the Fort McMurray area. Although Green's (1958) interpretation is based on the Precambrian surface at Exshaw time, this would be a close approximation of the general distribution of the highs and lows at Watt Mountain time, in fact Green's 2,250 foot contour line closely approximates the edge of the Peace River High at Watt Mountain time. If the above correlation and the areal placement of Kent's shelf is correct then normal marine conditions existed at the start of Watt Mountain time and continued at least until the end of the deposition of the dolomite member.

If the succession of the Watt Mountain Formation in the cores studied, is compared to the models of sedimentation of Visher (1965) the succession tends to suggest a regressive marine or deltaic sequence. From this suggestion, plus indications from the fauna and sedimentary structures, it is concluded that deposition took place in a near shore environment that ranged from shallow water marine to possibly continental nearer the Peace River High. At this point it should be mentioned again that there is a difference in feldspar content, type and amount of rock fragments and average grain size between sandstones in the Nipisi and Mitsue areas. The average

feldspar content of the thin sections examined in the Nipisi area is 32 percent of the essential components, while it is 22 percent in the Mitsue area. No igneous-metamorphic rock fragments or chert were found in the Mitsue area whereas they were noticed in samples from the Nipisi area. Also, the sandstones in the Nipisi area tend to be coarser grained than in the Mitsue area. The significance of these differences may be slight differences in composition of the source rock, different distances of transport, or dependency of the composition of the sandstone on grain size. The last two are more probably the important controlling factors. Examination of Figure 8 shows that a definite trend exists in the distribution of sandstone thickness within the Watt Mountain Formation. What is thought to be the most logical dispersion pattern, based on the limited areal extent of this study, is indicated by the red arrows. A dispersion pattern as shown on Figure 8 combined with a south south-eastward basin current could account for the compositional differences between the Mitsue and Nipisi area. As indicated on the dispersal pattern, sands in the Nipisi area probably were washed off the Peace River High directly to the site of deposition, while sands of the Mitsue area were transported for a longer distance before deposition.

This dispersal system could also account for the relatively high feldspar to quartz ratio observed in samples 262, 263, and 264. As was mentioned earlier, these samples represent a mudstone unit that appears to be fairly extensive areally in the Mitsue area. If south-southeast currents existed during Watt Mountain time, the larger feldspar to quartz ratio could be due to mud transportation from the north where there is more feldspar in the sandstone than in the Mitsue area. At the present time, however, this can only be a suggestion as no data exist on the composition of the mudstones in the Nipisi area.

Consistent with the above conclusions a more restricted interpretation of the environment of deposition might be suggested. It is felt that sandstones in the Mitsue area were deposited by a distributary system that produced either a compound delta

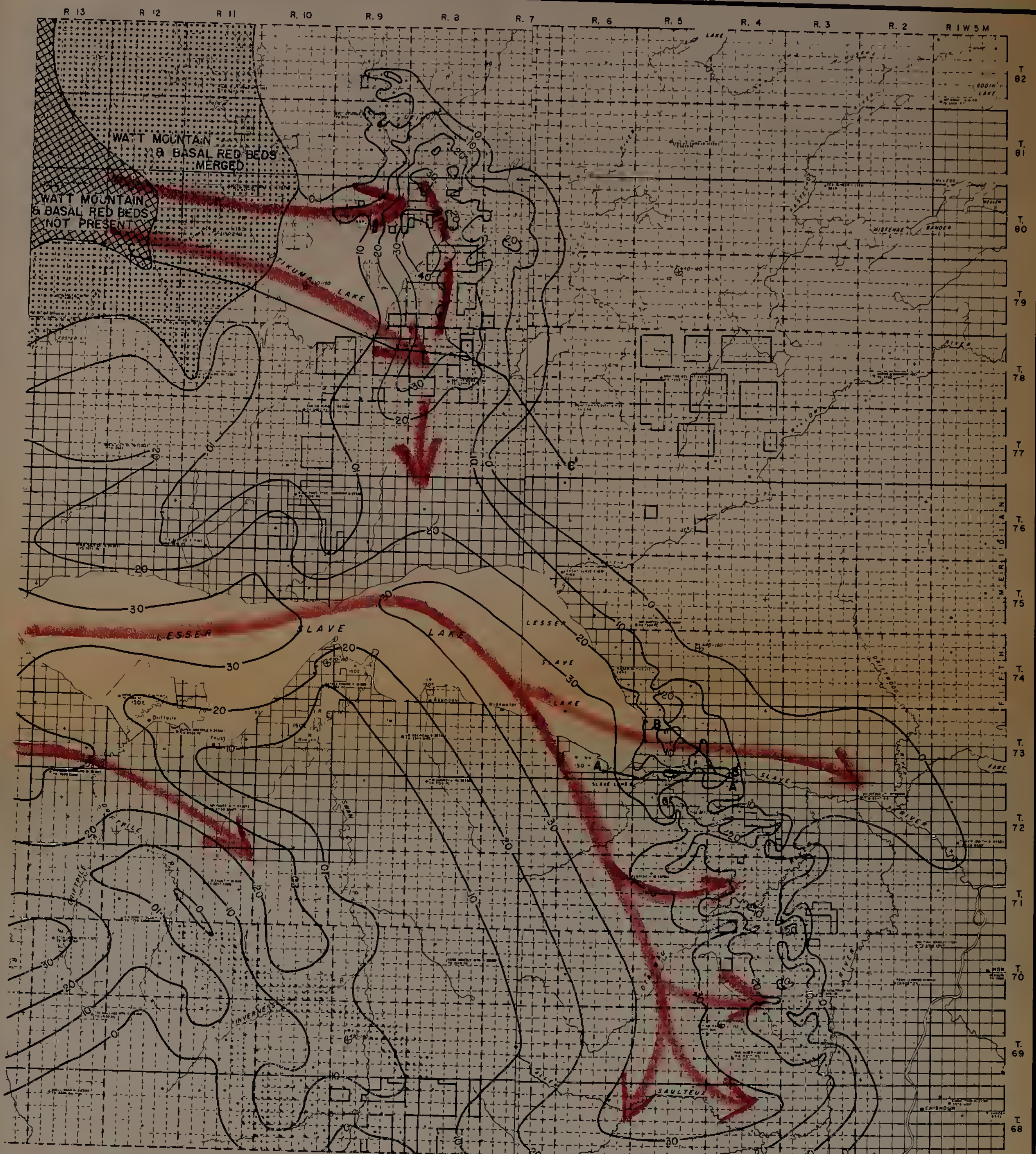
or was several short streams producing a coalescing "coastal flood plain" type of environment. Sandstones in the Nipisi area were probably deposited rapidly in a coastal flood plain after short, rapid transport off the Peace River High nearby. From the data available from the present study it is not possible to recognize continental versus brackish water marine deposits or to place a shoreline. Poor sorting, coarse size and basal scour of some of the sandstones indicates rapid influx and deposition without opportunity for reworking. This variation in activity of the depositing medium is likely related to climatic fluctuations and marked tectonism in the source area.

After deposition of the Watt Mountain Formation and its correlative First Red Beds in Saskatchewan, marine conditions returned to the area as the sea began to flood the Peace River High (Figure 9). This resulted in deposition of the Slave Point carbonates near the shorelines under perhaps pseudo-marine conditions (Sloss, 1953), while evaporites of the Fort Vermillion Member were deposited farther out in the basin. Because the Gilwood Sandstone contains a relatively large pore space plus cement plus matrix to grain ratio, it was cemented before deep burial and probably soon after deposition. The first cement to be precipitated appears to be the carbonate, because it is partly replaced by anhydrite. It may have come from carbonate-rich waters moving down from the overlying Slave Point carbonate muds and may have partly replaced matrix as well. The Gilwood sands would have provided excellent aquifers for transport of early compaction water from these muds. As depth of burial increased sulphate solutions from the Muskeg Formation and the Fort Vermillion Member of the Slave Point Formation probably infiltrated the Gilwood Sandstone from the opposite direction and replaced part of the carbonate cement and matrix. The mudstones, which appear to have only a small amount of anhydrite in them, were not affected as much as the sandstones because of their low permeability. However, some replacement of the mudstones and the dolomite member did take place as evidenced by anhydrite pods (Plate I-1, III-3, IV-1,2 and V-7) and small anhydrite veins (Plate V-8), attesting to the post-lithification time of this replacement.

Further Possible Studies

The present study of the Watt Mountain Formation should be regarded only as a preliminary investigation. Many questions are left unanswered and the writer feels that he only scratched the surface of information in the Watt Mountain. Further study and more data are needed to more closely delineate the environment or environments of deposition. This could possibly be accomplished by detailed mapping on a more regional scale, incorporating data from oriented cores and dip meter surveys to find the directional properties of the cross bedding that seems to be present in most of the Gilwood Sandstone. A study of the regional variations in grain size and sandstone composition would also be interesting and should aid in the study of dispersal patterns. A detailed study of the fauna and flora of the Watt Mountain Formation may eventually give valuable clues to the depositional environment and more exact age relationships with respect to other parts of the Elk Point basin. The Watt Mountain Formation could prove a very interesting study if the relationships between tectonics and the resulting sediment are examined.

In summary, as more data come out of the confidential files of the oil industry in western Canada, many questions will be answered and some created, and it is the opinion of the writer that much interesting and challenging work is yet to be done on the Watt Mountain Formation and the Gilwood Sandstone.



WATT MOUNTAIN Fm,
ISOPACH NET FEET OF SAND.

Figure 8.

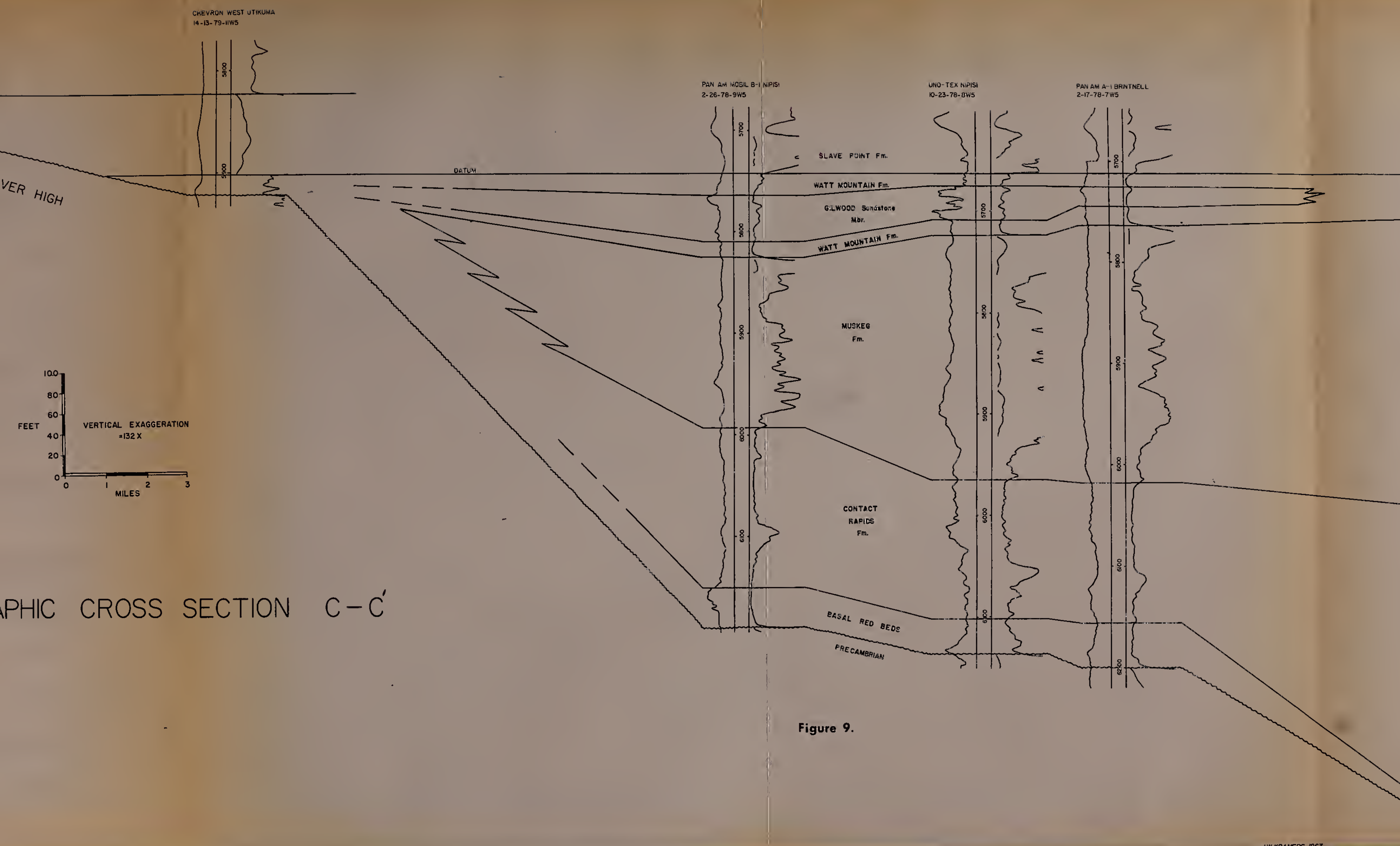

CHEVRON WEST UTIKUMA
14-13-79-11W5
PAN AM MOSIL B-1 NIPISI
2-26-78-9W5
UNO-TEX NIPISI
10-23-78-8W5
PAN AM A-1 BRINTNELL
2-17-78-7W5
DATUM
VER HIGH
SLAVE POINT Fm.
WATT MOUNTAIN Fm.
GILWOOD Sandstone
Mbr.
WATT MOUNTAIN Fm.
MUSKEG
Fm.
CONTACT
RAPIDS
Fm.
BASAL RED BEDS
PRECAMBRIAN
100
80
60
40
20
0
FEET
VERTICAL EXAGGERATION
=132 X
0
1
2
3
MILES
APHIC CROSS SECTION C–C′
J.W. KRAMERS 1967

Figure 9.

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PLATE I

Hand Specimen Photographs

Figure 1	Watt Mountain Formation (Unit 6); anhydrite replacement of extensively reworked mudstone. Note mudstone remnant (arrow) in anhydrite. (10-5-73-5W5, at 5474 ft.)
Figure 2	Watt Mountain Formation (Unit 6); showing a silty, sub-laminated (arrow), partially reworked zone in the mudstone. (12-7-73-4W5, at 5338 ft.)
Figure 3	Watt Mountain Formation; alternation of laminations and cross laminations. (7-6-79-7W5, at 5607 ft.)
Figure 4	Watt Mountain Formation (Unit 6); brecciation of silty laminae in mudstone. (12-7-73-4W5, at 5343 ft.)
Figure 5	Gilwood Sandstone (Unit 5); showing planar crossbedding. (12-13-73-5W5, at 5365.7 ft.)
Figure 6	Gilwood Sandstone (Unit 5); showing cross laminations. (12-7-73-4W5, at 5359 ft.)
Figure 7	Gilwood Sandstone (Unit 5); showing crossbedding, mudstone chips (arrows), poor sorting and reworking near top of picture. (12-7-73-4W5, at 5344.7 ft.)
Figure 8	Gilwood Sandstone (Unit 5); showing crossbedding and reworked mudstone laminae in upper half of picture. (4-4-73-4W5, at 5328 ft.)
Figure 9	Gilwood Sandstone (Unit 5); showing poor sorting and fish remains (arrows). (12-13-73-5W5, at 5377.3 ft.)
Figure 10	Gilwood Sandstone (Unit 5); showing mudstone chips, sub-laminations and partial reworking. (12-7-73-4W5, at 5345.5 ft.)

PLATE I

PLATE II

Hand Specimen Photographs

Figure 1	Gilwood Sandstone (Unit 5D); showing scour? and very poor sorting. (2-6-73-5W5, at 5550.5 ft.)
Figure 2	Gilwood Sandstone (Unit 5D); showing a slump-like feature with later infilling by sand. (2-6-73-5W5, at 5550.6 ft.)
Figure 3	Gilwood Sandstone (Unit 5A); interbedded to laminated sandstone and silty mudstone showing slump in the siltstone with later infilling by sand. (12-1-73-5W5, at 5392 ft.)
Figure 4	Gilwood Sandstone (Unit 5); silty, argillaceous sandstone showing a mount of very coarse to granule size grains with a finer grained matrix. (10-6-73-4W5, at 5336.8 ft.)
Figure 5	Watt Mountain Formation (Unit 3); siltstone showing a microfracture with authigenic chlorite or glauconite grains disseminating upwards (arrows) from the fracture. (10-3-73-6W5, at 5666.5 ft.)
Figure 6	Muskeg Formation showing brecciation of argillaceous anhydrite at the contact with the Watt Mountain Formation. (10-3-73-6W5, at 5680 ft.)

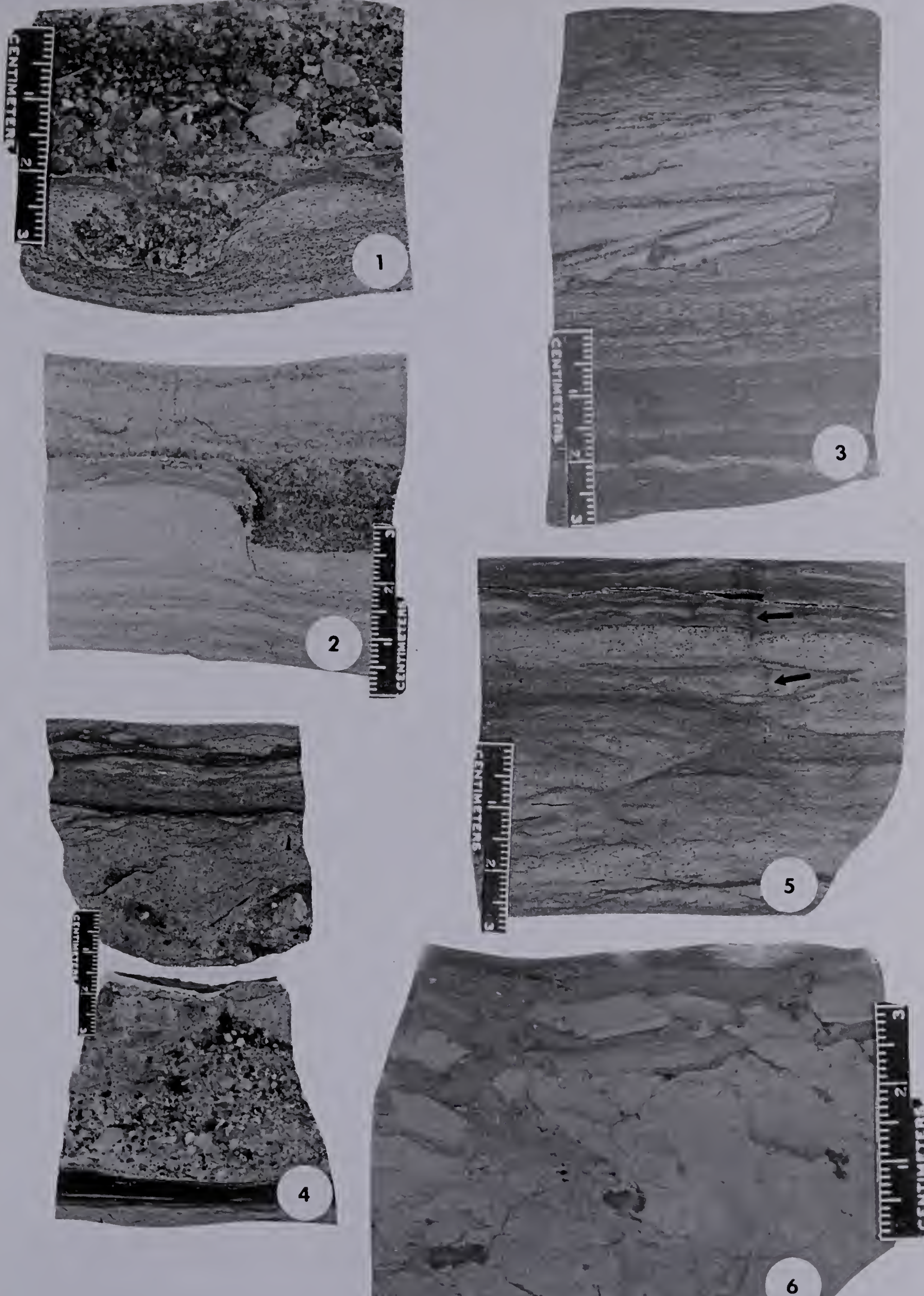

PLATE II

PLATE III

Hand Specimen Photographs

Figure 1	Watt Mountain Formation (Unit 3); very argillaceous, silty sandstone with mudstone zones, showing reworking of what was probably a laminated interval, also note limestone fragment (arrow) with a colored rim around the fragment. (4-4-73-4W5, 5344.3 to 5345.5 ft.)
Figure 2	Watt Mountain Formation (Unit 3); laminated sandstone, siltstone and mudstone showing scour and only slight reworking. Compare with Figure 1 which is just above this in the sequence. (4-4-73-4W5, 5347 to 5348 ft.)
Figure 3	Watt Mountain Formation (Unit 2); dolomite showing anhydrite replacement and limestone fragments (arrow) in a dolomite matrix just below the anhydrite pods. (4-4-73-4W5, at 5349.5 ft.)
Figure 4	Watt Mountain Formation (Unit 2); laminated dolomite and mudstone showing small scale fractures and a path for fluids during diagenesis. (10-5-73-5W5 at 5525.4 ft.)
Figure 5	Watt Mountain Formation (Unit 2); argillaceous dolomite showing an erosional surface. (10-3-73-6W5, at 5680 ft.)

PLATE III

PLATE IV

Thin Section Photomicrographs

Figure 1 Watt Mountain Formation (Unit 6); mudstone remnant in anhydrite pod, also note dolomite rhombs in anhydrite. (4-35-73-5W5, 5340 ft.), plane light, X67.5.

Figure 2 Watt Mountain Formation (Unit 6); contact of anhydrite pod and mudstone, note dolomite rhombs in mudstone and anhydrite, also silt size grains in mudstone and small remnant of mudstone in anhydrite. (4-35-73-5W5, 5340 ft.), plane light, X40.

Figure 3 Watt Mountain Formation (Unit 5B); color mottling in mudstone, note abundant dolomite rhombs in light-colored mudstone, also not brecciated appearance of dark patch. (4-35-73-5W5, 5357 ft.), plane light. X25.

Figure 4 Gilwood Sandstone (Unit 5); authigenic silica overgrowth on a rounded quartz grain, also note polycrystalline quartz cemented to central quartz grain by silica cement. (12-7-73-4W5, 5364 ft.), crossed nicols, X32.5.

Figure 5 Gilwood Sandstone; rounded quartz grain with authigenic silica overgrowths showing euhedral crystal faces at one end and replacement of overgrowth and nucleus by dolomite cement at the other end. (7-6-79-7W5, 5634.7 ft.), crossed nicols, X80.

Figure 6 Gilwood Sandstone; showing dolomite cement replacing quartz grain, also note authigenic silica overgrowth on same quartz grain which is not affected by the anhydrite cement, and joining of two quartz grains by silica cement. (10-26-78-8W5, 5653 ft.), crossed nicols, X100.

Figure 7 Gilwood Sandstone; showing dolomite cement replacing a quartz grain which is not affected by the anhydrite cement on the other side of the grain, also note strained quartz grain at top of the figure. (7-6-79-7W5, 5621.9 ft.), crossed nicols, X160.

Figure 8 Gilwood Sandstone; showing dolomite cement and anhydrite cement in contact, also note strained quartz grain cemented to non-strained quartz grain by silica cement. (10-26-78-8W5, 5653 ft.), crossed nicols, X40.

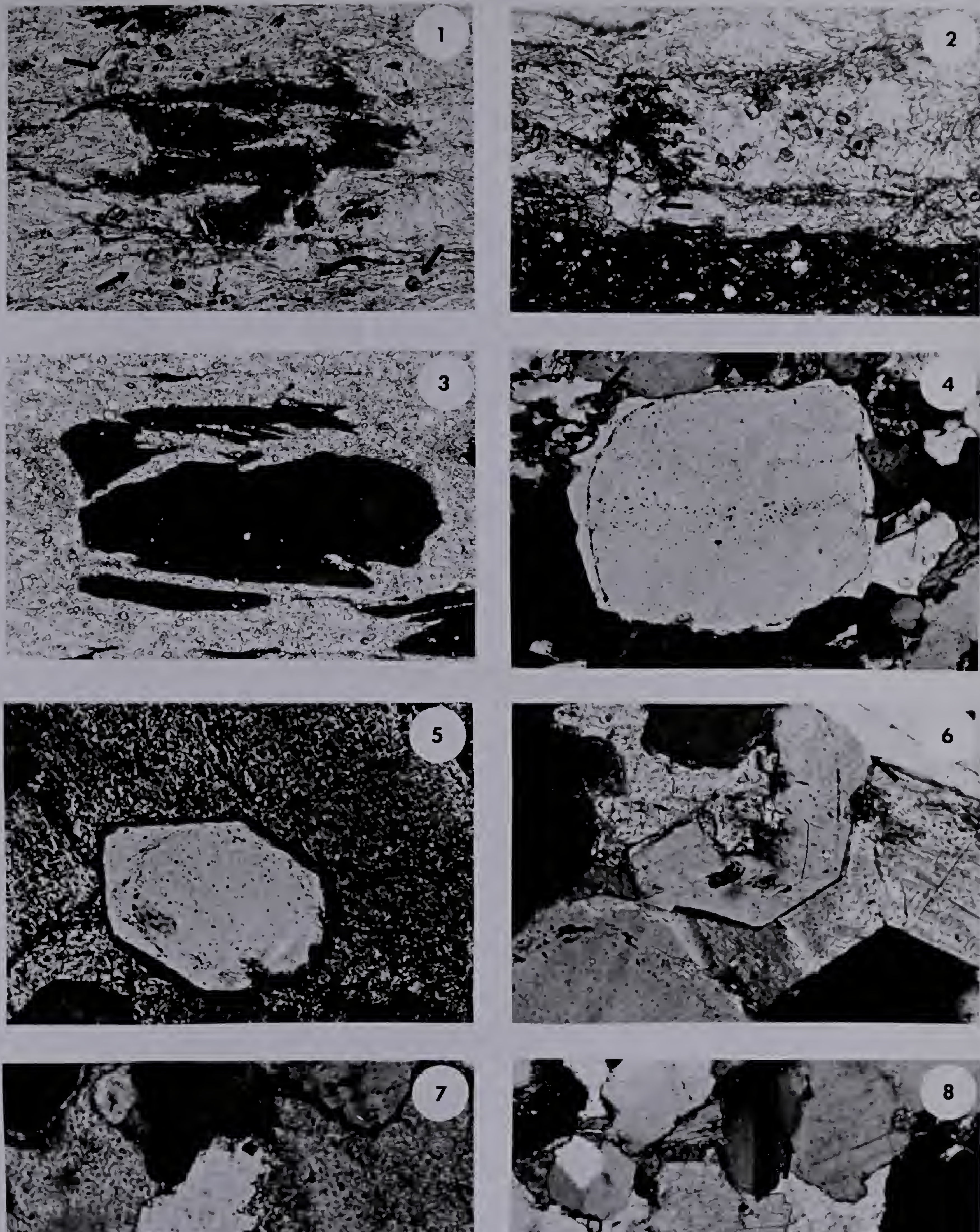

PLATE IV

PLATE V

Thin Section Photomicrographs

Figure 1	Gilwood Sandstone; K-feldspar being replaced by dolomite and anhydrite cement with the dolomite in turn being replaced by anhydrite, also note altered appearance of feldspar. (7-6-79-7W5, 5620 ft.), crossed nicols, X32.5.
Figure 2	Gilwood Sandstone; plagioclase partly replaced by anhydrite cement, also note worn quartz grain; (10-26-78-8W5, 5648 ft.), crossed nicols, X100.
Figure 3	Gilwood Sandstone (Unit 5); contact of matrix and anhydrite cement showing replacement of matrix by anhydrite cement (10-5-73-5W5, 5505 ft.), plane light, X25.
Figure 4	Gilwood Sandstone (Unit 5); untwinned feldspar grain being replaced by anhydrite cement, note worn appearance, well rounded partly altered feldspar grain at top of picture, polycrystalline quartz grain, and large cement to grain ratio. (10-28-73-5W5, 5423 ft.), crossed nicols, X32.5.
Figure 5	Gilwood Sandstone (Unit 5); polycrystalline quartz grains almost completely surrounded by anhydrite cement, note straining of individual quartz phases in the large polycrystalline quartz grain. (10-3-73-6W5, 5617 to 5657 ft.), crossed nicols, X25.
Figure 6	Watt Mountain Formation (Unit 2); dolomite composed almost entirely of rhombs with unidentifiable argillaceous material between the rhombs. (4-23-73-5W5, 5408 ft.), plane light, X67.5.
Figure 7	Watt Mountain Formation (Unit 2); anhydrite replacing dolomite in vein-like manner. (4-23-73-5W5, 5407 ft.), plane light, X25.
Figure 8	Watt Mountain Formation (Unit 2); random replacement of dolomite by anhydrite. (12-7-73-5W5, 5381.7 ft.), plane light, X25.

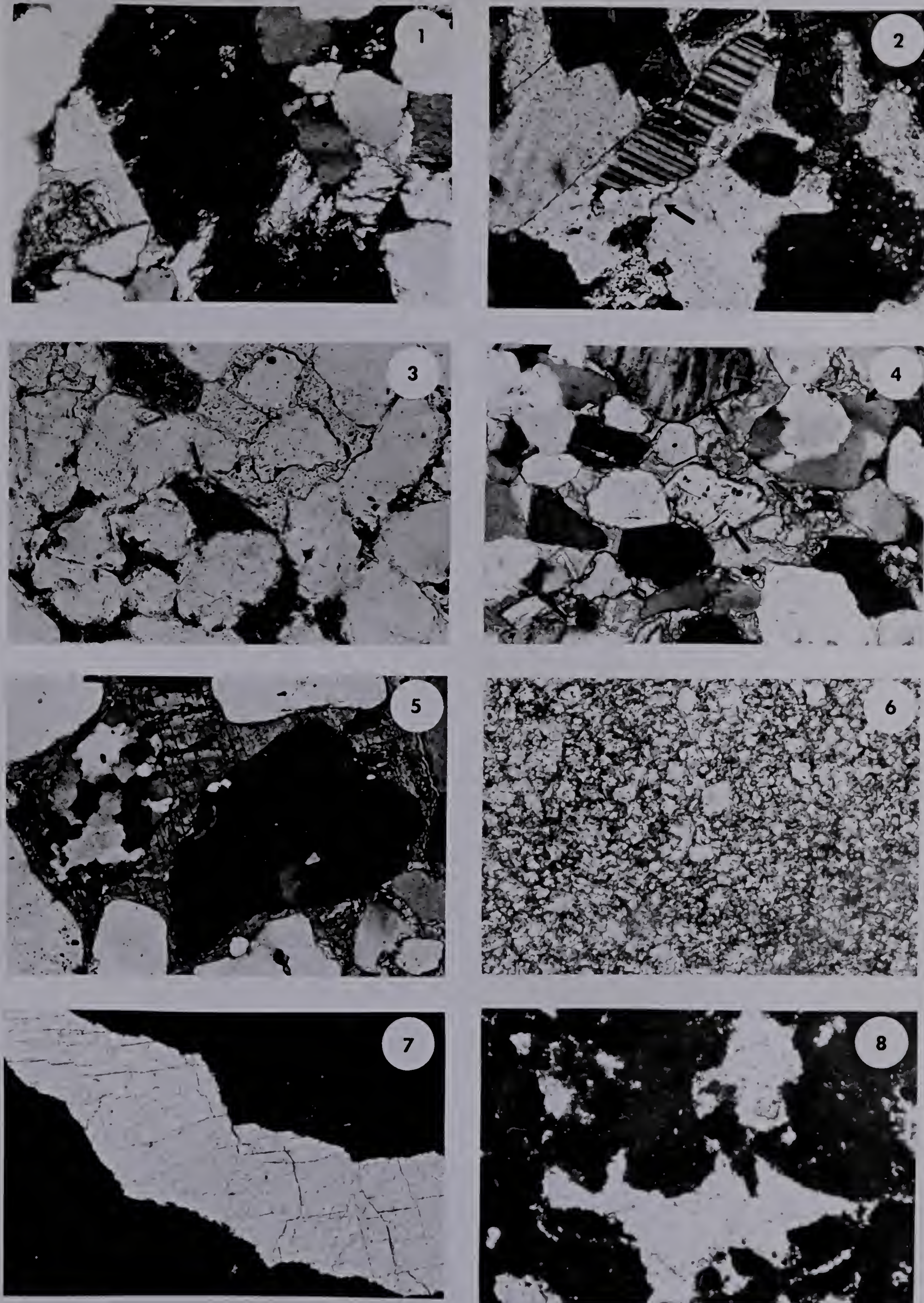

PLATE V

APPENDIX A

CORE DESCRIPTIONS

I.O.E. Mitsue 4-4-73-4W5 (KB 1925)

Core #1: 5310-5361 (rec.[1] 49.7/51 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
2.6'	Mdst., partly calc., silty, dk. greenish gray, uniform, very scat. frag. calc. org. remains occurring in a silty zone, grades into s.s. below.	5310-5312.6
Top of Gilwood s.s.		
5.7'	S.s., silty, arg., with several mdst. intbd., lt. greenish gray to dk. greenish gray, with some cln. lt. olive gray zones, scat. sh. chips, v.f.-f. gr., A.-r., well - mod. sorted, sub-lam.[2], xbd. in part, shows scour and reworking, scat. frag. fish remains esp. in upper part, mainly qtz., some fd., acc. are mica, pyrite and glauc., calc. and anhy. cement.	5312.6-5318.3
1.8'	Intbd. s.s., sltst., and mdst. on scale of less than 1", about 30% s.s., silty, arg., greenish gray to med. lt. gray, v.f.-m. gr., a.-r., well - mod. sorted, mainly qtz. and fd.; about 50% sltst., sandy, sh., greenish gray; about 20% mdst., silty, with scat. sand gr., dk. greenish gray, int. is partly lam., shows scour in basal part, worm burrows, pinch and swell, acc. are mica, glauc. and pyrite, some scat. org. remains in basal 2", basal contact is a scour contact.	5318.3-5320.1
5.3'	Mdst., silty in part, dk. greenish gray for 6", dusky brown for 2' and lt. greenish black for 2.7', structureless except for basal part of brown mdst. which appears to be brecciated, find *Cyzica* 1' above base.	5320.1-5325.4
4.1'	S.s., arg., silty in part, with some muddy zones, lt. greenish gray to greenish gray with some lt. olive gray zones, v.f.-f.gr., with some scat. m. and c. gr., well - mod. sorted, A.-r., small scale xbdg., sl. lam., ls. frag. at top of int., mainly qtz., and fd., acc. are mica and glauc., calc. and anhy. cement.	5325.4-5329.5
2.2'	Mdst., silty and sandy in part, sl. calc., dk. greenish gray grading to mot. greenish black to mod. brown at base with last 2" dk. greenish gray, org. remains at top, anhy. pod in top part, grades into int. below.	5329.5-5331.7

[1] A list of abbreviations used is given at the end of the appendix.
[2] Irregular, poorly developed laminae.

Thickness	Description	Depth (ft.)
3.7'	S.s., v. arg., silty to sltst. in part with some mdst. lam. at base, greenish gray and lt. brownish gray zones, v.f.-m. gr. with scat. c.-gran. gr., a.-R., poorly sorted with a v. high mtx. content, shows xbdg., reworking and slump features, scat. fish remains, mainly qtz. and fd., acc. are mica and glauc., basal 1' is about 60% mdst. and grades into next int..	5331.7-5335.4

Base of Gilwood s.s.

Thickness	Description	Depth (ft.)
6.1'	Mdst., silty in part with three sandy beds, partly calc. and anhy. (anhy. pod 1.5' from top), grayish brown with dusky brown mot. which appears to be partly due to brec., some zones show dk. greenish gray to greenish gray mot., scat. gr. from silt to gran. size, partly reworked.	5335.4-5341.5
2.3'	Mdst., silty, some sandy zones and pods in basal 1', dk. greenish gray with some blackish red discolorations around sandy zones, basal 1.3' appears reworked, acc. is mica.	5341.5-5343.8
2.7'	S.s., arg., silty, with mdst. zones, getting v. muddy to sandy mdst. in basal 0.7', calc., greenish gray to dk. greenish gray, v.f.-f. gr., a.-r., mod. sorted, with large proportion of mtx., ls. pod at 5345 with floating sand gr. and mod. yellow and grayish red rim, appears extensively reworked, sub-lam., microfract., basal muddy part has pockets of s.s. and worm burrows, comp. is mainly qtz. and fd..	5343.8-5346.5
1.6'	Intbd. to lam. s.s., sltst. and mdst. on scales of less than 1", calc. in part, appears to be same as int. above but not as extensively reworked, greenish gray to greenish black in basal 3", shows scour, pinch and swell, sh. chips, abnt. fish remains in upper 2", acc. are mica and glauc., two anhy. pods in basal 2".	5346.5-5348.1
0.7'	Intbd. dol. and sh. mdst. on a scale of about 1", dol., arg., lt. olive gray, aphanitic, anhy. in top part, shows pinch and swell of thin dol. lam., about 50% mdst., sl. calc., greenish black with fish remains.	5348.1-5348.8
1.0'	Dol., anhy. with some ls. frag. in basal 3", lt. olive gray with dk. greenish gray zones, aphanitic, two anhy. pods in upper part of interval (2"-3" thick), muddy beds in center are sl. distorted. (tilted w.r.t. rest of core).	5348.8-5349.8
1.7'	Dol., v. arg. to dol. mdst., olive gray to dk. greenish gray, aphanitic, lam. at the base and grades into next int.	5349.8-5351.5
2.9'	Mdst., silty with abnt. floating sand gr., partly calc. to anhy. in basal part, brownish gray with some dusky red mot.; basal 0.9' dk. greenish gray and dusky red mot., lower boundary is transitional.	5351.5-5354.4

Thickness	Description	Depth (ft.)
Top of Muskeg Fm.		
5.8'	Anhy., v. arg. to v. anhy. mdst., dk. greenish gray to brownish gray in basal 2', has floating frag. of apparently cln. anhy. esp. in basal 2'-3' with moderate yellow and dusky red rims around the more rounded fragments only, fragments are A.-R. and may be due to brec.	5354.4-5360.2

I.O.E. Sylvia 10-6-73-4W5 (KB 1901)

Core #1 5320-5328 (rec. 7/8 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
0.9'	Mdst., silty in park, dk. greenish gray, uniform and nondescript.	5320-5320.9
6.1'	Mdst., silty (esp. 1' from top, nearly a sltst.), greenish gray to dk. greenish gray depending on silt content, uniform and nondescript.	5320.9-5327.0

Core #2, 5328-5342 (rec. 13/14 ft.)

Thickness	Description	Depth (ft.)
Top of Gilwood s.s.		
2.2'	S.s., sh. at the base, lt. greenish gray, f.-c. gr. with beds that have a higher proportion of c. gr., mod. sorted, a.-r., xbd. in finer grains size beds, near base is a 1" v. silty and arg. bed, sub-lam. and shows pinch and swell, below this bed is 2" of poorly sorted arg. s.s. with gran.-pbl. size gr. of chloritic sh., comp. is mainly qtz. with scat. fd. and rock frag., acc. is glauc., anhy. cement.	5328-5330.2
0.7'	S.s., with silty and sh. lam. to mdst. in lower 1" of unit, partly anhy., v. lt. gray with grayish green lam. of mdst., v.f.-f. gr. with occasional gran. gr., poor-mod. sorted, a.-r., micro sub-lam., shows scour and reworking, lam. are wavy and not continuous, mainly qtz. and fd., acc. is mica and chlorite.	5330.2 5330.9

Thickness	Description	Depth (ft.)
5.9'	S.S., arg., silty, lt. olive gray with zones of lt. greenish gray, v.f.-m. gr., mod.-well sorted, a.-r., indications of xbdg., in basal 4" is a mount of v.c.- gran. size material with lath like org. remains, mount is about 1 1/2" high and composed of mainly qtz., some fd. and rock frag. and grades up into v. arg., f. gr. silty s.s. with some mdst. lam. showing scour and reworking, other mdst. lam. occur appr. 1' above base and also have indications of scour.	5330.9-5336.8
4.2'	Mdst., sl. calc., sandy to sh. s.s. at the top and very silty in upper 1', dk. greenish gray in top 1', brownish gray in central part and dk. greenish gray in basal 0.5', uniform except upper 1' which is micro sub-lam. in part, with org. remains (fish plates), central part is actually grayish green with red brown mot., basal part shows v. scat. mot. and v. scat. sand gr. and in places appears sl. fissile.	5336.8-5341.0

Core # 3, 5342-5352 (rec. 10/10 ft.)

Thickness	Description	Depth (ft.)
2.2'	Mdst., silty, anhy., grayish brown, uniform, mica scat. throughout int., scat. small pods of mod. green material (chlorite?), gets dk. greenish gray towards base with some grayish brown mot..	5342.0-5344.2
0.4'	S.s., arg., silty, with chloritic mdst. lam. near the base, greenish gray with dk. greenish gray mdst. bands, v.f.-m. gr. with scat. c.gr., a.-r., mod. -well sorted, small scale scour features and some disruption of mdst. bands prob. due to compaction, comp. is mainly qtz. and fd., acc. is chlorite.	5344.2-5344.6
1.9'	S.s., anhy., lt. greenish gray, f.-v.c. gr., a.-R., mod. -poorly sorted, xbd., comp. is mainly qtz. with scat. fd., anhy. is prob. cement, acc. is glauc., scat. pieces of org. remains.	5344.6-5346.5
1.2'	Mdst., anhy., getting silty and sandy towards base, dk. greenish gray, uniform except for a silty and sandy zone near the base, comp. of sand and silt is mainly qtz. and fd.	5346.5-5347.7
2.0'	Intb. s.s. and sltst. on order of inches; s.s., anhy., yellowish gray, f.-m. gr., a.-r., well sorted, xbd., comp. qtz. and fd.; sltst., sandy and shaly in part, lt. greenish gray, micro sub-lam. in part, scat. worm burrows, large org. remains (fish plates?), scat. v.c. sand grains; basal 4" is s.s., silty, arg., grayish green to dk. greenish gray with grayish brown mot., f.-v.c. gr., a.-R., poorly sorted, sub-lam., appears reworked, scat. org. remains, and discontinuous mdst. bands, comp. is mainly qtz. and fd.	5347.7-5349.7

Thickness	Description	Depth (ft.)
Base of Gilwood s.s.		
0.4'	Mdst., sandy and silty in v. thin layers, dk. greenish gray with black specks, uniform.	5349.7-5350.1
1.9'	Mdst., grayish brown with dusky brown mot., uniform, mot. may be frag..	5350.1-5352.0

Core #4, 5352-5371 (rec. 19/19 ft.)

Thickness	Description	Depth (ft.)
0.4'	Mdst., grayish brown with dusky brown mot., becoming grayish green towards the base, micro sub-lam., uniform.	5352.0-5352.4
2.6'	Mdst., silty in zones, dk. grayish green, and grayish brown with dusky brown mot. which appears to be frag., scat. sand size gr., acc. is glauc., gets v. silty near base and grades into next int.	5352.4-5355.0
5.2'	Sltst., sandy and arg. in part, pale yellowish green to grayish green with scat. grayish red mot., shows reworking, sub-lam., worm burrows, scour is shown below s.s. lam., v.f.-f. gr., well sorted, a.-r., mainly qtz., basal 3" is v. shaly and micro sub-lam. with glauc..	5355.0-5360.2
0.5'	Dol., arg. with mdst. lam., dk. yellowish brown, aphanitic, lam., small scale fracture in dol. lam.; mdst. intbd. are dk. greenish gray to greenish black.	5360.2-5360.7
1.3'	Mdst., silty, brownish gray and olive gray, micro sub-lam., appears sl. reworked.	5360.7-5362.0
2.2'	S.s., with intbd. of silty mdst. lam.; s.s., silty, arg., lt. greenish gray, v.f.-f. gr., r., well sorted; silty mdst. lam. are dk. greenish gray and anhy.; unit gets muddy near base and s.s. is minor in lowest 1 1/2", shows scour, reworking, small fract., lam. and sub-lam., pinch and swell of mdst. lam., comp. is mainly qtz. and fd., acc. is glauc..	5362.0-5364.2
0.6'	Mdst., silty, anhy. in part, sl. dol. in part at the base, dk. greenish gray and greenish black, sub-lam., v. silty at top of int. scat. fish remains, peaty in appearance.	5364.2-5364.8
2.1'	Dol., anhy., arg. near top and some mdst. lam. at top, pale yellowish brown, aphanitic, has anhy. pods near base (2" thick), bdg. appears disrupted by anhy. and have A. blocks of dol. floating in anhy..	5364.8-5366.9
1.7'	Mdst., silty, anhy. and dol., pale olive to dk. greenish gray, lam. and sub-lam., shows scour, becomes sh. towards base of interval, has a 0.1" thick sandy band near base with org. remains.	5366.9-5368.6

Thickness	Description	Depth (ft.)
2.1'	Mdst., dol. in part, silty, scat. sand gr. throughout, brownish gray with grayish brown mot. and scat. lt. green mot., uniform.	5368.6-5370.7

I.O.E. Mitsue 12-7-73-4W5 (KB 1915)

Core #1: 5334-5394 (rec. 60/60 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
10.0'	Mdst., silty in part, partly calc., anhy. in upper part, dk. greenish gray to greenish black, fairly homogeneous, sub-lam. and v. silty from 5338.5-5339, has occasional silty bands throughout rest of int.,some brec. at 5343.0 in a silty zone.	5334.0-5344.0
Top Gilwood s.s.		
3.3'	S.s., arg. and silty, anhy., with scat. sh.lam.,lt.gray in upper and lower part and yellowish gray in central part; top 1' and basal 1' are v.f.-c. gr., a.-r., mod. sorted, shows xbdg., badly sorted zones with gran. size material and some reworking, comp. is mainly qtz. and some fd. and rock frag.; central part is v.f.- m.gr., a.-r., well sorted, with some sh. lam., shows reworking, v. scat. gran. and sh. chips, appears more arg., has indications of xbdg., comp. is mainly qtz. and some fd., acc. are pyrite and glauc..	5344.0-5347.3
0.9'	Mdst., silty, especially in top part, grayish green, scat. sand gr., uniform, appears well reworked and has some remnant lam., acc. are pyrite and mica.	5347.3-5348.2
0.6'	S.s., partly anhy. plugged, arg. in part, lt. brownish gray to lt. gray, v.f.-m.gr., a.-r., well sorted, has mdst. chips, xbdg., some reworking of s.s., comp. is mainly qtz. and fd..	5348.2-5348.8
0.7'	Partly missing, prob. Sltst., muddy, sandy, anhy., greenish gray, sub-lam., scour contact with s.s. above, acc. are mica, pyrite and glauc..	5348.8-5349.5
1.3'	S.s., arg. in zones, some sh. lam., lt. olive gray, f.-m. gr., a.-r., well sorted, occasional lens-like zones with c.gr. which show xbdg., shows micro xlam. in more dirty parts and also mdst. chips (gran. size), comp. is mainly qtz. and fd..	5349.5-5350.8
1.0'	Mdst., sl. calc., silty with scat. sand gr., greenish gray to dk. greenish gray, interval is sub-lam., at base of int. is 0.2" thick lam. of poorly sorted s.s..	5350.8-5351.8

Thickness	Description	Depth (ft.)
0.8'	Mdst., dk. greenish gray, v. uniform and appears completely reworked.	5351.8-5352.6
2.2'	Mdst., med. dk. gray with grayish red mot. which in part may be frag., grades downward into an almost completely grayish red zone, uniform.	5352.6-5354.8
1.6'	Mdst., dk. greenish gray with greenish black mot. which may be remnants of lam. destroyed during diagenesis, uniform.	5354.8-5356.4
1.7'	Mdst., med. dk. gray with grayish red mot. grading down in basal 1' to grayish brown with scattered dk. greenish gray mot., uniform.	5356.4-5358.1
0.8'	Mdst., silty and sandy, greenish gray to dk. greenish gray with what appears to be part of a sand lens (2" thick) about 2" from base; sand is anhy. plugged, silty, lt. greenish gray, v.f.-f. gr., a., well sorted, has mdst. chips, comp. is mainly qtz. with some fd., acc. are glauc. and mica, adjacent to this sand body mdst. is sandy with v.f.-c. gr., is sub-lam. at the base and grades into next int..	5358.1-5358.9
2.3'	S.s., arg., silty, with shaly lam., pinkish gray to lt. brownish gray, v.f.-f. grained with some zones of v.f.-m. gr., a.-r., well- mod. sorted, shows micro xbdg. to micro xlam., lam. in part, org. remains (Antiarch bone plate), comp. is mainly qtz. with some fd., acc. is mica.	5358.9-5361.2
1.3'	Mdst., v. silty near top of interval, sandy and silty, dk. greenish gray, uniform.	5361.2-5362.5
4.3'	S.s., arg. and silty in part with sh. lam., partly anhy. plugged, pinkish gray to med. lt. gray, v.f.-f. gr., with zones of m.-c.gr., a.-r., well-mod. sorted, coarser bands grade up into finer bands, shows xbdg., micro xbdg., lam. and scour., coarser bands appear to be more anhy. plugged than finer gr. bands.	5362.5-5366.8
2.3'	S.s., anhy. plugged, lt. gray, v.f.-v.c. gr., a.-r., mod.-poorly sorted, xbd., org. frag., scat. gran. size frag., comp. is mainly qtz. and fd..	5366.8-5369.1
Base of Gilwood s.s.		
0.8'	Mdst., partly calc., greenish gray, sub-lam., acc. is scat. pyrite.	5369.1-5369.9
1.6'	Mdst., grayish red to grayish brown, lower 1' is silty and has org. remains (Antiarch bone plate), partly lam. and appears somewhat reworked, has part of a very poorly sorted sand lens near base which has sh. frag. and org. remains in it.	5369.9-5371.4

Thickness	Description	Depth (ft.)
1.7'	S.s., arg., silty, grayish orange pink, v.f.-f. gr., a.-r., well sorted, sub-lam., appears to be partly reworked, comp. is mainly qtz. and some fd., acc. are mica and glauc..	5371.4-5373.1
0.6'	Mdst.., grayish green, with scat. org. remains (Antiarch plate), scat. sand gr., acc. is glauc..	5373.1 5373.7
1.2'	Mdst., dk. greenish gray with brownish gray mot. which may in part be due to brec., lam. at top of int..	5373.7 5374.9
1.0'	Mdst., grayish olive green, uniform, has org. remains (Cyzica).	5374.9-5375.9
1.6'	Mdst., silty, dk. greenish gray with a sltst. zone which is greenish gray, sub-lam., some scat. reddish brown mot. in basal part, acc. in glauc..	5375.9-5377.5
1.0'	Sltst., muddy, greenish gray, with dk. greenish gray to greenish black lam., shows reworking of an originally lam. sequence, micro frac., acc. is glauc..	5377.5-5378.5
1.3'	Intbd. mdst., silty mdst. and sltst. on scale of less than 1"; upper part is mainly mdst. and silty mdst., dk. greenish gray to greenish black; central portion is mainly sltst., greenish gray with disrupted lam.; lower 4" is silty mdst. and mdst., greenish black and grades into next int..	5378.5-5379.8
3.1'	Intbd. shaly mdst. (greenish black) and arg. dol. (yellowish gray to lt. greenish gray); upper 7" is intbd. dol. and mdst. on scale of less than 1"; basal 2.4' is mainly dol. (80%) with some mdst. lam.; dol. is aphanitic, anhy., exhibits lam. which are curved in basal portion, contact with next int. is sharp.	5379.8-5382.9
1.2'	Mdst., dol. to v. arg. dol. with sh. mdst. lam., greenish gray to dk. greenish gray, lower contact is sharp.	5382.9-5384.1
1.7'	Mdst., partly dol., lt. brownish gray with brownish gray mot., becomes anhy. in basal part, scat. silt and sand gr. grades into next int..	5384.1-5385.8
Top of Muskeg Fm.		
7.5	Anhy., arg. to anhy. mdst., dk. greenish gray with dusky red to v. dk. red mot. frag. of cln. looking anhy. with discoloration rims around the R. frag..	5385.8-5393.3

I.O.E. Mitsue 12-1-73-5W5 (KB 1907)

Core #1: 5372-5419 (rec. 47/47 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
5.0'	Mdst., silty in part,dk. greenish gray, uniform and structureless, acc. is v. scat. pyrite crystals.	5372.0-5377.0
Top of Gilwood s.s.		
2.6'	S.s., sl. arg., anhy. and calc. in part, lt. greenish gray, v.f.-c. gr. with some silt size material, A.-r., poorly sorted, some dk. greenish gray zones which are mainly silt and arg. material, shows reworking, sh. chips, comp. is mainly qtz. with some fd. and rock frag., acc. are scat. pyrite, mica and glauc., basal 2" is v. arg. and grades into next int..	5377.0-5379.6
1.1'	Intbd. sltst., v.f. gr. s.s. and silty sandy mdst., lam. on a scale of less than 1", arg., anhy., lt. greenish gray to dk. greenish gray, extremely poorly sorted, sand gr. are v.f.-v.c. gr., A.-R., shows sub-lam. to lam. ghosts, reworking, comp. is mainly qtz., and fd. with some rock frag., acc. are glauc. and pyrite, sand content decreases with depth.	5379.6-5380.7
3.0'	S.s., arg. in part, yellowish gray with greenish gray zones, v.f.-m. gr., a.-r., well-mod. sorted, shows signs of xbdg., reworking, lam., comp. is mainly qtz. with some fd., acc. are scat. glauc., pyrite and chlorite, esp. in greenish gray zones.	5380.7-5383.7
1.3'	Intbd. s.s., sltst. and silty mdst. on order of less than 1"; s.s., silty, greenish gray, v.f.-m. gr., a., well sorted, sub-lam., slightly reworked, some zones are v. arg., grades into sltst., which is sandy; mdst. is silty and sandy, dk. greenish gray with v. dusky red zones and mot.; most of the s.s. appears at top of the interval and mdst. is most abnt. near the base, comp. is mainly qtz. and fd., acc. are mica, glauc. and pyrite, unit appears lam. and sl. reworked.	5383.7-5385.0
0.9'	Intbd. to lam. sltst. and silty mdst. on a scale of less than 1", greenish gray to dk. greenish gray, scat. sand size gr., uniform except for lam., acc. are chlorite and glauc..	5385.0-5385.9

Thickness	Description	Depth (ft.)
1.0'	Mdst., silty, partly calc., dk. greenish gray, uniform and not very competent.	5385.9-5386.9
1.4'	Mdst., dk. greenish gray with grayish red to blackish red mot. which is erratic in nature, uniform.	5386.9-5388.3
1.8'	Mdst., partly calc., org. remains (Cyzica, Eochara wickendeni, Chovanella burgessi, and Cephalaspid type plates), uniform, gets silty and sandy in basal 1.5" and grades into next int..	5388.3-5390.1
1.4'	S.s., arg., silty, lt. greenish gray to greenish gray, v.f.-m. gr., a.-r., well sorted, shows xbdg., scour at base, calc. org. remains (fish plates), comp. is mainly qtz. with some fd., acc. are glauc. and mica.	5390.1-5391.5
3.8'	Intbd. s.s. and silty mdst.; about 30% s.s., arg., silty, anhy. plugged, pinkish gray, v.f.-f. gr. a.-r., well sorted, shows xbdg., mdst. chips, reworking, slump and scour; about 70% mdst., silty, brownish gray to brownish black with the occasional dk. greenish gray zone, partly lam., shows some reworking of lam., acc. is mica.	5391.5-5395.3
4.1'	Sltst., sandy to arg., with some intbd. v. poorly sorted s.s. bands, partly calc., dk. greenish gray with brownish gray to brownish black mot. to complete replacement of dk. greenish gray color, appears nearly completely reworked with some relict lam., acc. are mica (in random orientations) and glauc., appears to be the same as the int. above only much more reworked.	5395.3-5399.4
Base of Gilwood s.s.		
2.0'	Mdst., silty to arg. sltst. at the base, dk. greenish gray to brownish gray in basal part with brownish gray mot. in in the central part, has org. remains, acc. is mica (or chlorite).	5399.4-5401.4
1.2'	Mdst., silty in upper part, greenish gray and dk. greenish gray zones with some brownish gray mot. near the top of the int., lam. to sub-lam., reworked near the top, micro fract., brec. of lam..	5401.4-5402.6
0.9'	Mdst., silty and sandy near base, partly calc., brownish gray with some greenish gray inclusions at the base where it is nearly an arg. sltst., upper part is almost mot. (red on green) and may be brec., lower silty part is rather poorly sorted with org. remains.	5402.6-5403.5
1.2'	Mdst., partly calc., greenish gray with brownish gray to brownish black mot. and replacement in basal 5", lam. of sandy mdst. in lower part.	5403.5-5404.7

Thickness	Description	Depth (ft.)
1.0'	Sltst. to v.f. gr. s.s., arg., lt. greenish gray, silty - v.f. gr., a.-r., well sorted, some brownish gray mot., appears extensively reworked, comp. is mainly qtz. and fd., acc. are mica and glauc..	5404.7-5405.7
1.3'	Mdst., dk. greenish gray with brownish gray to brownish black mot., some of which may be frag..	5405.7-5407.0
2.0'	Intbd. s.s. and mdst.; s.s. is arg., greenish gray with brownish gray discoloring in it, silty - f. gr., A.-r., mod. sorted, comp. is mainly qtz. and fd., acc. are glauc. and pyrite; mdst. is dk. greenish gray, shows rupture and brec. and towards base becomes black and org. looking.	5407.0-5409.0
2.6'	Intbd., sltst. and mdst. on a scale of less than 1"; sltst. , sandy to silty v.f. gr. s.s., lt. greenish gray; mdst. is silty, dk. greenish gray, shows reworking (originally was prob. lam.), sub-lam., scour, brec. of thin lam., gets lam. towards base and sh. and grades into next int..	5409.0-5411.6
1.4'	Intbd. to lam. sh. and dol. (scale is less than 1"); about 70% sh., dk. greenish gray to greenish black, fish remains, sl. fissile; about 30% dol., arg., lt. olive gray, sl. banded, becomes anhy. in lowest 3", shows disruption of lam. and what may be a fluid path during diagenesis in which dol. frag. float in an apparently anhy. calc. muddy mtx..	5411.6-5413.0
1.7'	Mdst., partly calc., dk. greenish gray, scat. fish remains, grading down into a lam. arg. dol., partly anhy., lt. olive gray to lt. greenish gray, some lam., small scale scour, pinch and swell of lam..	5413.0-5414.7
1.9'	Mdst., partly calc., pale yellowish brown in upper half to pale brown to grayish brown in basal half, due to dusky red mot., uniform and prob. reworked, has v. scat. frag. of anhy. and near base has a thin zone with scat. qtz. sand.	5414.7-5416.6
Top Muskeg Fm.		
2.0'	Anhy., arg., to v. anhy. mdst., dk. greenish gray, with dusky red to v. dk. red mot. around what appears to be frag. of cln. anhy., some of which also have a yellowish orange rim, these discoloration rims are usually only found around the R. frag. and not the A. frag..	5416.6-5418.6

I.O.E. Sylvia 12-3-73-5W5 (KB 1911.5)

Core #1: 5407-5456 (rec. 48.5/49 ft.)

Thickness	Description	Depth (ft.)
Slave Point Fm.		
5.0'	Ls., v. arg. to v. calc. mdst., partly anhy., dk. greenish gray and olive black, lam. to sub-lam., 4-5" zone of anhy. at base.	5407.0-5412.0
Top Watt Mountain Fm.		
11.8'	Mdst., silty, with some muddy sltst. zones, dk. greenish gray, scat. sub-lam., reworking in zones not sub-lam., scat. anhy. pods, gets sandy towards basal part of int..	5412.0-5423.8
Top of Gilwood s.s.		
2.1'	Intbd. s.s. and sltst. on scale of less than 1" with some scat. s.s. beds of 1-2"; s.s., arg., silty, grading into sltst., lt. greenish gray, v.f.-f. gr., a.-r., well to mod. sorted, lam. to sub-lam., shows sl. reworking, comp. is mainly qtz. and fd., acc. are mica and glauc.; sltst., arg., greenish gray and grades into s.s.; scat. mdst., lam. are dk. greenish gray.	5423.8-5425.9
1.8'	S.s., arg., some minor mdst., lam., yellowish gray to lt. greenish gray, v.f.-m. gr., a.-r., mod.sorted, with scat. c. and v.c. gr. and mdst. chips, shows xbdg., scour, deformation of lam., comp. is mainly qtz., acc. are mica and glauc..	5425.9-5427.7
1.3'	Missing due to plugs.	5427.7-5429.0
1.5'	S.s., arg., anhy. plugged, cgl., pale greenish yellow to lt. gray, f.-c. gr. with zones that are f.-gran. gr., a.-R., mod.-poorly sorted, scat. mdst. chips, org. remains, no apparent sed. structures, comp. is mainly qtz., with some fd. and rock frag., acc. is pyrite.	5429.0-5430.5
1.9'	S.s., arg., partly anhy. plugged, lt. olive gray, f.-m. gr. scat. zones with c.-v.c. gr. and gran., a.-r., mod.-poorly sorted, xbd. due to gr. size differences, gets coarser gr. to cgl. in basal 6", comp. is mainly qtz.	5430.5-5432.4
1.7'	S.s., arg., partly anhy., lt. gray to v. lt. gray, abnt. mdst. chips, f.-c. gr. with scat. v.c. and gran. gr., a.-R., poorly sorted, shows scour contact at base, comp. is mainly qtz., with some fd. and rock frag., acc. are mica and glauc..	5432.4-5434.1

Thickness	Description	Depth (ft.)
0.9'	S.s., arg., lt. olive gray, f.-m. gr., a.-r., mod. sorted with v. scat. c. -v.c. gr., xbdg. is shown by variation in gr. size, comp. is mainly qtz. with scat. fd..	5434.1-5435.0
0.4'	Mdst. with some intbd. s.s.; (80%) mdst., silty and sandy, dk. greenish gray, partially sub-lam., acc. are mica and pyrite; (20%) s.s., arg., silty, v. lt. gray, v.f.-f. gr., well sorted, occurs as lam. in mdst., comp. is mainly qtz., acc. are mica and glauc..	5435.0-5435.4
15.7'	S.s., sl. arg., partly anhy. plugged yellowish gray to lt. olive gray, f. -m. gr., with some zones which are f.-v.c. gr., a.-R., well - mod. sorted, well xbd. in places, which is accentuated by differential anhy. plugging (in coarser gr. lam.) and variation in gr. size, some elongated gr. appear to be oriented parallel to xbds., two shaly lam. 3' above base of unit, parallel to xbds., comp. is mainly qtz. and fd., acc. is mica.	5435.4-5451.1
3.2'	S.s., partly anhy., yellowish gray to lt. olive gray, zones of f.-m. gr. with scat. v.c. gr., A.-R., mod.-poorly sorted, xbdg. is well developed in upper half, comp. is mainly qtz. with scat. fd..	5451.1-5454.3
0.7'	Missing due to plugs, prob. s.s. as above.	5454.3-5455.0
0.7'	S.s. as below.	5455.0-5455.7

Core #2: 5456-5481 (rec. 25/25 ft.)

Thickness	Description	Depth (ft.)
3.2'	S.s., partly anhy. plugged, v. lt. gray with some yellowish gray and dk. gray due to o.s., f.-c. gr. with scat. v.c. gr., a.-R., mod.-poorly sorted, xbdg. can be seen due to differential o.s. in basal 2", includes large (1x6 cm.) phenoclast of chloritic arg. s.s., and a triangular shaped frag. of well sorted, well calc. cemented f.-m. gr. s.s. made up entirely of qtz. gr.; boundary with s.s. below is sharp, comp. is mainly qtz. and some fd..	5455.7-5458.2
1.2'	S.s., silty and arg. in part, lt. brownish gray, v.f.-med. gr. with scat. c. gr. near the base, A.-r., well sorted for most part, xbdg. is suggested by mdst. lam. near base, comp. is mainly qtz. with some fd., acc. is mica.	5458.2-5459.4

Thickness	Description	Depth (ft.)
Base of Gilwood s.s.		
0.8'	Mdst., greenish gray to dk. greenish gray, uniform, becoming sandy towards the base and grading into next int..	5459.4-5460.2
3.5'	S.s., silty, arg. and calc. in part, v. lt. gray to lt. greenish gray, v.f.-f. gr., well sorted, intbd. with some sandy sltst. lam. which are greenish gray, interval is sub-lam., reworked, shows scour, has a 1" dol. bed which is sandy, comp. is mainly qtz. with some scat. fd., acc. are mica and glauc..	5460.2-5463.7
0.8'	Mdst., dk. greenish gray, uniform, scat. org. frag..	5463.7-5464.5
3.5'	Intbd. sltst. and s.s. with sltst. being predominant, lt. greenish gray to greenish gray; s.s. is arg., v.f.-f. gr., well sorted, has abnt. mdst. frag. in upper 2" of interval and just below this a dol. nodule with floating sand gr. in it very similar to dol. bed in s.s. above, also has scat. mdst. lam., int. also shows reworking and pinch and swell, acc. are mica and glauc..	5464.5-5468.0
1.0'	Intbd. mdst. and sltst. on a scale of less than 1"; mdst. is dk. greenish gray and sltst. is lt. greenish gray to greenish gray, sub-lam., org. remains (Cyzica), grades into next int.	5468.0 5469.0
0.8'	Intbd. mdst. and dol. on a scale of about 0.2"; dol., arg. in part, lt. olive black, aphanitic; mdst., greenish black with scat. org. remains.	5469.0 5469.8
2.5'	Dol. with several shaly and v. arg. dol. intbd.; (90%) dol. is in two beds appr. 1' thick each; upper bed-shaly streaks, v. arg. in upper 5", v. lt. gray to lt. gray, aphanitic, pinch and swell of sh. lam.; lower bed - arg. in upper 6"; in between two dol. beds are mdst. lam. with v. scat. org. remains (Cyzica); basal 2" is dol. dk. green mdst. to muddly dol..	5469.8-5472.3
0.6'	Intbd. s.s. and sltst. on the order of less than 1"; s.s., v. arg. with abnt. mtx., pinkish gray; sltst., muddy, greenish gray, shows scour, mdst. chips, scat. org. remains, and appears tightly cemented.	5472.3-5472.9
2.3'	Sltst., v. arg., calc. in part, scat. sand gr., lt. brownish gray to brownish gray with brownish gray mot., sand gr. are f.-m. gr. and lower half is v. sandy, shows scour at basal contact, reworking and some brec. in upper half.	5472.9-5475.2
1.1'	Mdst., greenish gray, v. uniform, lower 4" has some anhy., replacement with reaction rims around the anhy..	5475.2-5476.3

Thickness	Description	Depth (ft.)
4.8'	Anhy., v. arg. to anhy. mdst., dk. greenish gray, abnt. frag. of cln. anhy., a.-w.R., with a dusky red rim around the R. and w.R. frag. only.	5476.3-5481.1

I.O.E. Sylvia 10-5-73-5W5 (KB 1911)

Core #1: 5461-5518 (rec. 57/57 ft.)

Thickness	Description	Depth (ft.)
Slave Point Fm.		
6.0'	Ls., arg. to v. calc. sh., with some lam. of dk. greenish gray calc. mdst., olive black, lam. to sub-lam., brec. in upper part, at base is a 0.6' zone of olive dol. ls. which also shows brec., some pinch and swell, anhy. replacement.	5461-5467
Top of Watt Mountain Fm.		
12.2'	Mdst., silty, dk. greenish gray, sandy towards the base, uniform, some anhy. replacement in form of pods, appears well reworked.	5467.0-5479.2
Top of Gilwood s.s.		
1.4'	S.s., arg., sh., partly anhy. plugged, yellowish gray and greenish gray to lt. greenish gray, f.-m. gr. with scat. c. and v.c. gr., A.-r., mod. sorted, appears well reworked, comp. is mainly qtz. with scat. fd. and rock frag., acc. are mica, pyrite and glauc..	5479.2-5480.6
14.6'	S.s., arg. in part, calc. in part, partly anhy. plugged, yellowish gray to lt. gray with a dk. gray zone at the base due to o.s.; two different gr. size units: a) v.f.-f. gr. with the occasional m. and c. gr., A.-r., well sorted, comp. is mainly qtz. with some scat. fd.; and b) f.-v.c. gr. with scat. gran. size gr., occasionally cgl. with a f. gr. matrix, A.-R., poorly sorted, these coarser zones appear to be effected more by the anhy. plugging than the finer gr. zones; these units alternate and grade into each other and usually are less than 5"-6" with a minimum size of a few tenths of an inch; also a mdst. band at 5485.5 which is dk. greenish gray and above which are several mdst. chips in the s.s.; there are also scat. shaly streaks between 5485.5 and 5488 in arg. s.s. zones; unit as a whole is xbd., basal 0.8' is lam., scat. fish remains, comp. is mainly qtz. and acc. are v. scat. mica and glauc., basal contact is a scour contact.	5480.6-5495.2
3.3'	Mdst., calc. in part, dk. greenish gray, scat. fish remains, waxy in appearance, appears reworked, grades quickly into s.s. below.	5495.2-5498.5

Thickness	Description	Depth (ft.)
2.3'	S.s., silty in part, partly calc. and anhy., lt. greenish gray to lt. yellowish gray, v.f.-f. gr., A.-r., well sorted, some shaly streaks near top, xlam. and xbd., appears reworked in part, grades into int. below, comp. is mainly qtz. with some fd. and rock frag., acc. are mica and scat. glauc. or chlorite.	5498.5-5500.8
7.1'	S.s., partly calc. and anhy. plugged, lt. greenish gray to yellowish gray, f.-c. gr., some coarser and some finer zones, A.-R., mod.-poorly sorted, xbd. in part (no indication of xbdg. in upper 2'), scat. fish remains, scat. gran. size gr. and mdst. chips in basal part of unit, comp. is mainly qtz., with some fd., acc. is mica.	5500.8-5507.9
0.6'	Mdst., to lam. s.s. and mdst. ; (40%) s.s., v. silty, arg., lt. greenish gray, v.f.-f. gr., A.-a., mod. sorted, mainly in upper part; (60%) mdst., silty, dk. greenish gray, mainly in lower part.	5507.9-5508.5
0.9'	S.s., partly anhy. plugged, yellowish gray to lt. greenish gray, m.-gran. gr., mod.-poorly sorted, has scat. mdst. chips and fish remains, comp. is mainly qtz. with some fd., acc. is glauc..	5508.5-5509.4

Base of Gilwood s.s.

Thickness	Description	Depth (ft.)
0.6'	Mdst., sandy and silty, dk. greenish gray, uniform with scat. mica and fish remains.	5509.4-5510.0
2.8'	Intbd. sltst., s.s., and mdst., on a scale of 1" or so, lt. greenish gray to dk. greenish gray, different lithologies grade into each other, shows scour, lam., reworking, poor sorting and there are inclusions of sltst. and mdst. in s.s. zones, grades into next int..	5510.0-5512.8
4.8'	Mdst., silty and sandy in part, dk. greenish gray with grayish brown mot., which in part may be due to brec., grades into int. below.	5512.8-5517.6

Core #2: 5518-5540 (rec. 21/22ft.)

Thickness	Description	Depth (ft.)
4.4'	Intbd. s.s., sltst. and mdst. on a scale of 1" or so, with a dol. bed 1" thick 4" from top; s.s., arg., lt. greenish gray, f.-m. gr., a.-r., well sorted; color of unit as a whole is lt. greenish gray to dk. greenish gray with some grayish brown mot. near the top, unit is mainly mdst. in basal part, s.s. and sltst. in central part and sltst. and mdst. in upper part, shows reworking, lam., some brec., pinch and swell and grades into next int..	5518.0-5522.4
1.1'	Sh. to mdst., greenish black to grayish black with some dol. lam. near base, has org. remains (Cyzica, Antiarch scales) acc. is pyrite.	5422.4-5423.5

Thickness	Description	Depth (ft.)
2.3'	Dol., sl. arg., yellowish gray to lt. gray to lt. greenish gray with some mdst. intbd. in basal half which are dk. gray to grayish black; basal 4" is lam. dol. and mdst., showing fractures and scat. brec. and grades into next int.; upper half is more uniform with scat. mdst. lam..	5423.5-5425.8
0.8'	Mdst., v. silty and sandy, sl. calc., silt and sand size material occurs in pockets or v. small lenses, dk. greenish gray and grades into next int. with a color change.	5425.8-5426.6
2.6'	Mdst., silty and scat. sand gr., sl. calc., greenish gray to lt. brownish gray with some grayish brown mot., appears extensively reworked and grades into next int..	5426.6-5429.2
1.2'	Mdst., dk. greenish gray, uniform, it is prob. a transition between int. above and int. below, it is sl. calc. at top and sl. anhy. at base and grades into int. below.	5429.2-5430.4
Top of Muskeg Fm.		
9.7'	Anhy., arg., to v. anhy. mdst., dk. greenish gray at top grading to brownish gray near the base with some grayish red rim like mot. around R. anhy. frag., rims do not occur around A. frag., very similar to same interval in other cores.	5430.4-5440.1

I.O.E. Sylvia 2-6-73-5W5 (KB 1915.7)

Core #1: 5518-5547 (rec. 29/29 ft.)

Thickness	Description	Depth (ft.)
Slave Point Fm.		
1.7'	Ls., arg., dk. greenish gray with scat. brownish gray mot., cryptocrystalline; lower 0.5' is dol., arg., lt. gray, aphanitic, with intbd. of sltst., med. dk. gray, acc. is pyrite.	5518-5519.7
Top of Watt Mountain Fm.		
11.0'	Mdst., dol. in part, silty, dk. greenish gray, uniform and structureless.	5519.7-5530.7
Top of Gilwood s.s.		
2.4'	S.s., arg., partly calc., v. lt. gray to lt. gray, v.f.-c. gr., a.-r., mod. sorted, micro sub-lam., appears reworked, v. arg. near base, acc. are mica and glauc., upper contact is gradational over about 1".	5530.7-5533.1

Thickness	Description	Depth (ft.)
2.2'	S.s., sl. arg., partly anhy. plugged, yellowish gray, f.-m. gr., with scat. c. and v.c. gr., near top of the interval, A.-a., mod. sorted, appears well reworked, comp. is mainly qtz. with scat. fd., acc. are glauc., pyrite and mica.	5533.1-5535.3
2.9'	S.s., sl. arg., partly anhy., yellowish gray, f.-c. gr., a.-r., mod. sorted, comp. is mainly qtz. with some fd., acc. are mica, glauc. and pyrite.	5535.3-5538.2
4.8'	S.s., partly calc., partly anhy. plugged, lt. gray, m.-v.c. gr. with a v.f. gr. mtx., a.-r., mod.-poorly sorted, xbd., comp. is mainly qtz. and some fd., with some dusky yellow green ls. frag. (1"x.3") near the base, acc. is pyrite.	5538.2-5543.0
4.0'	S.s., partly anhy. plugged, partly calc., sl. arg., with several sh. lam., yellowish gray, f.-m. gr., with some lam. of f.-c. gr., a.-r., mod. sorted, shows scour near the base of the interval, xbd., comp. is mainly qtz., with scat. fd. and rock frag., acc. are glauc. and pyrite.	5543.0-5547.0

Core #2: 5547-5582 (rec. 35/35 ft.)

Thickness	Description	Depth (ft.)
3.1'	Mdst., calc., partly sandy, dk. greenish gray to grayish green near the base, some reddish mot. near base, contains org. remains (Antiarch scales), uniform.	5547.0-5550.1
1.4'	Intbd. s.s. and sltst. on the order of a couple of inches or so, with some lam. of mdst.; s.s., arg., silty, pbl. in part, yellowish gray, v.f.-f. gr. in some beds and m-pbl. gr. in others, A.-R.- mod.-poorly sorted, shows microfrac. and scour, comp. is mainly qtz. with some fd., acc. is mica; sltst. is sandy and muddy in part, dusky yellowish green to grayish green, lam. to micro lam., acc. are glauc. and mica.	5550.1-5551.5
1.9'	Mdst., anhy., silty, dk. greenish gray, uniform with scat. sand gr..	5551.5-5553.4
3.3'	Intbd. s.s. and sltst. on a scale of about 1" or less; s.s., arg., anhy. plugged, yellowish gray, v.f.-f. gr. in zones and other zones are f.-c. gr., a.-R., mod. to poorly sorted, comp. is mainly qtz. and some fd., acc. are mica, chlorite and glauc.; sltst., sandy, anhy., grayish green, with mica and chlorite acc.; interval as a whole shows scour and some reworking.	5553.4-5556.7
1.6'	S.s., sl. arg., yellowish gray, f.-c. gr., with scat. v.c. gr., a.-r., poorly sorted, xbd., comp. is mainly qtz., with some fd., acc. is pyrite.	5556.7-5558.3

Thickness	Description	Depth (ft.)
Base of Gilwood s.s.		
1.0'	Mdst., anhy., sandy, grayish green, most of this interval is missing.	5558.3-5559.3
1.9'	Mdst., partly anhy., rich in org. remains (Antiarch scales), olive gray to grayish green, appears sandy in part, some red mot. in upper part, uniform.	5559.3-5561.2
2.3'	Mdst., anhy., v. silty in part, grayish green at the top to dusky red at the base, has a 1" s.s. bed at the top which is arg., anhy., greenish gray, f.-c. gr., a.-r., poorly sorted, mainly qtz.; mdst. has scat. sand gr., micro and sub-lam., acc. is glauc..	5561.2-5563.5
2.1'	Mdst., anhy., sandy, grayish olive green with v. dusky red mot. in upper foot of int., uniform with v. scat. org. remains (Antiarch scales) and sand gr..	5563.5-5565.6
0.3'	Dol., calc., dk. yellowish brown, aphanitic, with some intbd. sh. lam. showing a boudinage like structure in top 1".	5565.6-5565.9
1.4'	Mdst., anhy., dusky yellowish green in the basal half of int. and grayish olive green with v. dusky red mot. in upper half of the int., uniform.	5565.9-5567.3
1.6'	S.s., v. silty, with intbd. shaly lam., lt. gray to grayish olive green, silty to v.f. gr., a., mod. sorted, shows reworking and small scale scour, comp. is mainly qtz. with minor fd., acc. is mica.	5567.3-5568.9
0.9'	Mdst. to silty sh., anhy., greenish black, fossiliferous (*Cyzica* cf. *membranacea*), sub-lam., sl. fissile.	5568.9-5569.8
4.7'	Dol., arg. and anhy. in part, lt. olive gray, aphanitic, with dk. greenish gray mdst. lam. at the top and bottom of interval with central part relatively cln., 3" from base lam. are on scale of about 0.1".	5569.8-5574.5
2.4'	Mdst., anhy., dusky yellow green to dk. yellowish brown with grayish red mot., center one-third of int. is silty to sandy and scat. silt and sand gr. occur in rest of interval, uniform.	5574.5-5576.9
Top of Muskeg Fm.		
3.4'	Anhy., v. arg. to v. anhy. mdst., grayish olive green, v. uniform with frag. of what appears to be pure anhy., which are A.-R. with a dusky red and reddish orange rim around the R. frag., acc. is pyrite.	5576.9-5580.3
1.7'	Anhy., arg., dk. greenish gray, appears lam., acc. is pyrite.	5580.3-5582.0

I.O.E. Sylvia 12-13-73-5W5 (KB 1904)

Core #1: 5330-5387 (rec. 57/57 ft.)

Thickness	Description	Depth (ft.)
Slave Point Fm.		
14.3'	Ls., arg., to v. calc. mdst., lt. olive gray to olive gray with intbd. zones of dk. greenish gray, lam. to sub-lam., shows scour, brec., and replacement by anhy.	5330.0-5344.3
Top of Watt Mountain Fm.		
13.3'	Mdst., partly calc., and anhy., silty in part, greenish gray to dk. greenish gray, has pods of anhy. v. scat. throughout, lam. to sub-lam. in silty part in center, appears reworked, gets v. silty and sandy near base and grades into next int., acc. is pyrite.	5344.3-5357.6
Top of Gilwood s.s.		
3.4'	Intbd. s.s. and mdst. on a scale of an inch or so; about 10% mdst., silty, greenish gray to dk. greenish gray up to 1" thick; about 90% s.s., silty, partly anhy. plugged, arg., yellowish gray and grayish red, v.f-f. gr. with scat. c.-pbl. gr. occurring in zones that fine upwards, a.-r., mod. sorted, lam. to sub-lam., xbd., shows scour, comp. is mainly qtz. with some fd. and mdst. frag. in s.s., acc. in chlorite and glauc..	5357.6-5361.0
5.7'	S.s., sl. arg., partly anhy. plugged with minor mdst. streaks, yellowish gray to lt. olive gray, f.g.-m. gr. with scat. c. and v.c. gr., A.-r., well-mod. sorted, xbd., comp. is mainly qtz. with scat. fd..	5361.0-5366.7
6.4'	Mdst., greenish gray to dk. greenish gray with zones of brownish gray mot. which may in part be due to brec., scat. sand and gran. size gr., uniform, acc. is mica near top of int..	5366.7-5373.1
2.7'	Intbd. mdst., sltst. and silty s.s. on a scale of 1" or less; about 60% mdst., greenish gray to dk. greenish gray, with scat. inclusions of sltst. to s.s.; about 30% sltst., sandy in part, lt. greenish gray to greenish gray, acc. are mica and glauc.; about 10% s.s., arg., silty, partly anhy. plugged, med. lt. gray, silty to c. gr., a.-r., mod.-poorly sorted, comp. is mainly qtz. with some fd. and mdst. frag., acc. is glauc., int. as a whole shows scour, lam. and sub-lam., some brec., some reworking.	5373.1-5375.8
1.6'	S.s., sl. arg., silty, partly anhy. plugged, yellowish gray with med. gray discolorations due to o.s., v.f.-f. gr., a.-r., well sorted, with one lam. that has scat. c. gr. in it, sl. indication of micro xlam. near the base, xbd. near the top, comp. is mainly qtz..	5375.8-5377.4

Thickness	Description	Depth (ft.)
0.3'	S.s., arg., silty with shaly streaks, pinkish gray to lt. gray, v.f.-f. gr., a.-r., well sorted, with scat. v.c. gr., sub-lam., appears sl. reworked, comp. is mainly qtz. with scat. fd., acc. are mica and glauc..	5377.4 5377.7
5.7'	S.s., partly anhy. plugged, pbl. in part, med. lt. gray with zones of yellowish gray to lt. olive gray, f.-v.c. gr. with scat. gran. and pbl. size gr., A.-r., poorly sorted with phases of f.-m. gr., a.-r., well sorted; poorly sorted sand grades up into better sorted, but poor sorting is exhibited best toward the top of the int., whole unit is xbd. and differentially anhy. plugged, comp. is mainly qtz. with scat. fd., acc. are mica and glauc. and scat. org. (fish) remains.	5377.7-5383.4

Base of Gilwood s.s.

Thickness	Description	Depth (ft.)
0.8'	Mdst., dk. greenish gray, silty in part, calc. in part, uniform, appears reworked.	5383.4-5384.2
0.9'	Mdst., silty, greenish gray with brownish gray mot. which appears to be due entirely to brec.	5384.2-5385.1
1.9'	Intbd. mdst., silty mdst. and silty s.s. on a scale of about 1"; about 60% mdst., pale brown to grayish brown with scat. silt and sand size gr., appears completely reworked with scat. remnants of lam., has scat. org. remains; about 20% silty mdst., like the mdst. but siltier and lighter in colour; about 20% s.s., silty, arg., lt. brownish gray, silty-v.f. gr., a.-r., well-mod. sorted, int. as a whole exhibits scour and slump, acc. are mica and glauc..	5385.1-5387.0

I.O.D. Mitsue 4-23-73-5W5 (KB 1910)

Core #2: 5351-5378 (rec. 27/27 ft.)

Thickness	Description	Depth (ft.)

Slave Point Fm.

Thickness	Description	Depth (ft.)
7.6'	Ls., anhy. in part, arg. with some sh. intbds., mainly olive black with some dk. greenish gray lam., aphanitic to cryptocrystalline, lam. to sub-lam., brec. in part, shows pinch and swell of lam. and scour, 0.5' thick unit of dol., olive gray at the base.	5351.0-5358.6

Top of Watt Mountain Fm.

Thickness	Description	Depth (ft.)
12.0'	Mdst., silty in part, partly anhy. and calc., greenish gray to dk. greenish gray, has anhy. pods in it, is lam. to sub-lam. in part and appears to be reworked, becomes sandy in basal 2" and grades into next int..	5358.6-5370.7

Top of Gilwood s.s.

Thickness	Description	Depth (ft.)
1.5'	S.s. with mdst. intbds.; about 70% s.s., partly anhy. plugged, partly calc., partly arg. and partly cln., v. lt. gray to lt. greenish gray, f.-v.c. gr. with scat. gran. gr., A.-R., poorly sorted, scat. org. remains, appears well reworked, comp. is mainly qtz. with some fd. and mdst. frag., acc. are mica, pyrite in org. remains and glauc.; about 30% mdst. intbds., dk. greenish gray, sub-lam..	5370.6-5372.1
2.2'	S.s., arg. in basal part, partly anhy. plugged, v. lt. gray to lt. brownish gray, f.-v.c. gr., with scat. gran. gr., gr. size tends to decrease downward, A.-R., mod.-poorly sorted, large scale planar xbd. in basal part of interval, comp. is mainly qtz. with scat. fd. and rock frag., acc. is glauc., basal contact is sharp and appears to be erosional.	5372.1-5374.3
3.7'	Ss. with intbd., sltst. (20%) and mdst. (15%), on a scale of several inches and lam.; s.s., partly anhy., sl. arg., silty, lt. brownish gray to v. lt. olive gray, v.f.-f. gr., A.-r., well sorted, shows small scale xbdg., sub-lam., sl. coarser gr. near base, comp. is mainly qtz. with some fd.; sltst., sl. sandy and sh., greenish gray to dk. greenish gray, lam. in part, appears reworked; mdst. is in sub-lam. s.s. and in sltst. 0.9' sltst. and mdst. 1.0' arg. s.s., shaly in upper 2" 0.6' lam. s.s., sltst. and mdst. 1.2' arg. s.s.	5374.3-5378.0

Core #3: 5378-5392 (rec. 14/14 ft.)

Thickness	Description	Depth (ft.)
10.0'	V. poor rec. consisting of appr.; a) 1.5', sltst., ss. and intbd. mdst.; s.s., arg., silty, sl. calc., lt. brownish gray to greenish gray, v.f.-m. gr., A.-R., well to mod. sorted, no structures can be identified, comp. is mainly qtz. with some fd., acc. is mica; sltst. is sandy in part, greenish gray and has scat. mica; mdst. is dk. greenish gray; b) 8.5', mdst., silty in part, with zones of brownish gray and dk. greenish gray, appears uniform, brownish gray zones appear to be due to extensive mot., scat. org. remains (Antiarch bone plate).	5378.0-5388.0

Thickness	Description	Depth (ft.)
1.1'	Intbd., sltst., (40%), mdst. (35%) and s.s. (25%); sltst., shaly and sandy in part, greenish gray, grades into mdst. which is dk. greenish gray and shows sub-lam., reworking, brown mot., floating sand and pbl. size gr.; s.s., arg., silty, v. lt. brownish gray, v.f-f. gr. to v.f.-c. gr. in part, A.-r., well to poorly sorted, lam. with sltst. and mdst., shows scour, comp. is mainly qtz., acc. is mica.	5388.0-5389.1
2.9'	Mdst., with abundant pbl. to sand gr. to cgl. in central part of interval, greenish gray and grayish brown, A.-R., v. poorly sorted; cgl. bands from 5390.0-5391.5, v. sandy with scat. gran. from 5389.1-5390.0, also grayish brown frag. of mdst. in cgl. zones and org. remains (bone frag.), cgl. zones are v. poorly cemented and fragile, comp. is mainly qtz. with some fd. and mdst. frag., basal 3" is v. arg. shaly s.s., v.f.-f. gr. with scat. gran. and pbl. size gr., poorly sorted, comp. is mainly qtz. with some fd., acc. are glauc., whole interval appears to have been rapidly dumped in place.	5389.1-5392.0

Base of Gilwood s.s.

Core #3: 5392-5416 (rec. 24/24 ft.)

Thickness	Description	Depth (ft).
10.0'	Mdst., silty in part to sltst., greenish gray to dk. greenish gray with grayish red zones and some grayish brown mot. which may in part be due to brec., have some scat. floating sand size gr. and some scat. sandy bands, sub-lam., appears extensively reworked, acc. is glauc., contacts with int. above and below appears to be abrupt.	5392.0-5402.0
0.9'	Sltst., sandy to v. silty s.s., sl. calc. in part, with mdst. lam. (about 10%), greenish gray with some mod. red discoloration in upper and basal few inches, A.-a., int. is silty-v.f. gr., well-mod. sorted, appears extensively reworked, basal contact is sharp and may be erosional, comp. is mainly qtz. with scat. fd., acc. are glauc. and chlorite.	5402.0-5402.9
0.6'	Sltst., v. arg., sandy in part, partly calc., dk. greenish gray to greenish black, appears to have been reworked from originally lam., shows brec., org. remains towards base, comp. is mainly qtz. with scat. fd., acc. are mica, glauc. and pyrite, grades into int. below.	5402.9-5403.5
0.7'	Sh., silty in part, olive black, abnt. org. remains (Cyzica, ganoid type scale, Acanthodid spine), silt content decreases downward.	5403.5-5404.2

Thickness	Description	Depth (ft.)
2.6'	Dol., arg. in part with intbd. (25%) sh. mdst. lam., lt. olive gray, aphanitic, appears to have been lam. in part and then reworked, shows pinch and swell, micro-fract., has some v. calc. dol. or ls. frag. near base, grades into int. below.	5404.2-5406.8
1.0'	Dol., arg. and sh. near base, anhy. in part, gray to yellowish gray, aphanitic, has frag. of ls. floating in it which are A., grades into int. below.	5406.8-5407.8
0.3'	Dol., with intbd. mdst. lam., v. lt. olive gray to dk. greenish gray, microcrystalline, mdst. is sandy and silty in part, appears to have been sl. reworked.	5407.8-5408.1
0.3'	S.s., arg., dol., to dol. with floating sand gr., greenish gray, f.-m. gr., r.-R., well sorted, grades into int. above and below.	5408.1-5408.4
1.2'	Mdst., dol. and anhy. in part, greenish gray with abnt. brownish gray mot., with scat. dk. yellowish orange inside mot., scat. floating sand gr., grades into int. below.	5408.4-5409.6
6.3'	Anhy., v. arg., dk. greenish gray to brownish gray in basal 1.5 ft., scat. A.-w.R. frag. of cln. anhy. with a brownish gray rim around the R. frag., which are most common in central 2' or so of the int..	5409.6-5415.9

I.O.E. Mitsue 10-28-73-5W5 (KB 1918)

Core #1: 5386-5401 (rec. 15/15 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
12.9'	Mdst., silty in part with several sandy zones in basal 5", partly anhy., dk. greenish gray, shows reworking in the more silty parts, brec. of lam., pods of anhy. which sometimes have pyrite around the margin, grades into next int..	5386.0-5398.9
Top of Gilwood s.s.		
2.1'	S.s., partly anhy. plugged, arg. and silty to arg. sandy sltst. in top 6", lt. gray to greenish gray, f.-m. gr., A.-a., well to mod. sorted, indications of xbdg., lam. in upper part, appears reworked in basal portion, comp. is mainly qtz. with scat. fd., acc. are mica and glauc..	5398.9-5401.0

Core #2: 5401-5420 (rec. 19/19 ft.)

Thickness	Description	Depth (ft.)
0.6'	Mdst., dk. greenish gray, sub-lam., shows brec. of lam., and some scour, int. not well represented.	5401.0-5401.6
0.4'	Dol., arg., with sh. lam., partly anhy., lt. olive gray to olive gray, aphanitic, shows pinch and swell of sh. lam., acc. is pyrite in sh. lam..	5401.6-5402.0
1.8'	S.s., silty in part, partly anhy. plugged, yellowish gray to lt. brownish gray, f.-m. gr. in upper part and f.-c. gr. with scat. v.c. gr. in basal portion, A.-r., well-mod. sorted, indications of xbdg., scour, comp. is mainly qtz. with scat. fd..	5402.0-5403.8
3.3'	Intbd. s.s. (30%) and arg. sltst. (60%) on a scale of less than 1", lt. greenish gray to greenish gray with some dk. greenish gray mdst. bands (10%); s.s., arg., v.f.-v.c. gr. with scat. pbl. gr., a.-R., poorly sorted; sltst., arg. and sandy in part; int. as a whole is sub-lam. and shows reworking, scour and scat. org. remains (fish plates) in central portion, comp. is mainly qtz. with scat. fd., acc. are mica, glauc. and chlorite.	5403.8-5407.1
1.7'	Mdst., silty and sh. in part, dk. greenish gray to greenish black, shows brec. and reworking of sub-lam., pinch and swell, grades into int. below.	5407.1-5408.8
5.4'	Mdst., upper 2.6' is grayish brown and lower 2.8' is dk. greenish gray with grayish brown mot., abnt. org. remains from 5411.8-5413 (fish remains), uniform and appears well reworked, grades into int. below.	5408.8 5414.2
5.7'	Intbd. mdst. (50%), sltst. (30%) and s.s. (20%) on a scale of 1" or less; s.s., arg., silty, lt. gray to lt. brownish gray, v.f.-m. gr., mod. sorted in upper 1.5', v.f.-pbl. gr.,poorly sorted in central portion and v.f.-m. gr., mod. sorted in basal portion; sltst., arg., sandy in part, greenish gray; mdst., silty and sandy, dk. greenish gray to greenish black and partly grayish brown in top 1'; int. shows lam., mdst. chips in s.s. lam., scour, reworking; comp. of s.s. and sltst. is mainly qtz. with scat. fd. and mdst. chips, acc. are mica and glauc..	5414.2-5419.9

Core #3: 5420-5440 (rec. 19.5/20 ft.)

Thickness	Description	Depth (ft.)
6.2'	S.s., partly calc. and anhy. plugged, v. lt. gray to lt. brownish gray, f.-c. gr., A.-r., mod.-poorly sorted with zones of v.c.-pbl. gr. with a v.f.-f. gr. mtx., scat. sh. lam., scat. org. remains (bone frag.), large scale planar xbdg., comp. is mainly qtz. with scat. fd., grades into int. below.	5419.9-5426.1

Thickness	Description	Depth (ft.)
0.8'	Intbd. s.s. and minor mdst.; s.s. beds are 1"-2" thick, arg., partly anhy., greenish gray to lt. greenish gray, f.-pbl. gr., A.-R., poorly sorted, comp. is mainly qtz. with scat. fd., acc. is glauc.; mdst. beds are about 1/2" thick, dk. greenish gray; whole int. shows scour and fish remains.	5426.1-5426.9
Base of Gilwood s.s.		
1.0'	Mdst., dk. greenish gray, uniform.	5426.9-5427.9
0.6'	Mdst., dk. greenish gray with grayish brown mot. which is not due to brec.	5427.9-5428.5
1.5'	Mdst., silty, greenish gray to dk. greenish gray with grayish brown discoloration zones, has a 1" bed of v. poorly sorted pbl. s.s. near the top and org. remains above the s.s. bed, remainder of int. is uniform, acc. are mica and glauc..	5428.5-5430.0
0.9'	Mdst., dk. greenish gray with grayish brown mot. which may in part be due to brec.	5430.0-5430.9
0.5'	Mdst., dk. reddish brown with some dk. greenish gray mot., shows lam. in lower half and upper portion appears completely reworked.	5430.9-5431.4
1.5'	Mdst., dk. greenish gray with grayish brown mot. which does not appear to be due to brec.	5431.4-5432.9
2.2'	Sltst., v. arg., anhy. in part, sandy in part with shaly zones, lt. greenish gray to dk. greenish gray, appears well reworked, shows scour, has scat. org. remains, comp. is mainly qtz. with scat. fd..	5432.9-5435.1
1.0'	Mdst., sh., dk. gray to v. dk. greenish gray, abnt. fish remains (Antiarch scales, bone plates) in dk. gray zones, acc. is pyrite concentrated mainly in dk. gray zones.	5435.1-5436.1
1.8'	Dol., arg. esp. in upper 0.6' which is nearly a dol. mdst., lt. olive gray to olive gray, aphanitic, lam. in upper 0.6', acc. is pyrite.	5436.1-5437.9
1.6'	Dol. with intbd. mdst. lam.; lower 0.4' is dol., arg., lt. olive gray, aphanitic, uniform; upper 1.2' is lam. dol. and dol. mdst. (sandy in part), dk. gray, showing pinch and swell.	5437.9-5439.5

I.O.E. Sylvia 10-3-73-6W5 (KB 1914)

Core #3: 5601-5617 (rec. 13.2/16 ft.)

Thickness	Description	Depth (ft.)
Watt Mountain Fm.		
	Mainly mdst. similar to that found above the Gilwood s.s. in other wells, top of Watt Mountain Fm. is prob. below a dol. stringer whose base is 1' below top of rec. core; mdst. is silty, uniform, at base of recovered core are some silty sand and sltst. lam. similar to the top of the Gilwood in 2-6-73-5W5.	

Core #4: 5617-5657 (rec. 15.3/40 ft.)

Gilwood s.s.

Rec. consists mainly of s.s., arg. in part, cln. in part, lt. olive gray to yellowish gray, f.-c. gr. with some zones that are pbl., A.-r., mod. sorted, anhy. plugging seems to be concentrated in the coarser gr. zones, shows good planar xbdg. throughout.

Core #5: 5657-5684 (rec. 27/27 ft.)

Thickness	Description	Depth (ft.)
1.6'	Intbd., s.s. (90%) and silty mdst.(10%); s.s., arg. in part, partly anhy. plugged, lt. greenish gray to lt. brownish gray, v.f.-f. gr., a., well sorted, appears reworked, comp. is mainly qtz.; mdst., silty, dk. greenish gray.	5657.0-5658.6
0.6'	Dol. (60%), intbd. with mdst. lam (40%); dol., arg., lt. olive gray, aphanitic; mdst., dk. gray to grayish black.	5658.6-5659.2
3.7'	Sltst. (70%) with some intbd. s.s.; sltst., shaly to mdst., dk. greenish gray; s.s., arg., silty, lt. gray, v.f.-f. gr., a., mod. sorted; int. as a whole shows lam., reworking, worm burrows, plant remains (Psilophytes) and some fish scales, becomes dk. greenish gray sh. mdst. in basal 1'.	5659.2-5662.9
0.4'	Dol., lt. olive gray, aphanitic, lam., with minor mdst. bands.	5662.9-5663.3
1.2'	Mdst., silty, olive gray with scat. s.s. patches, appears reworked, appears v. org.-rich.	5663.3-5664.5
3.5'	Intbd. s.s., sltst. and minor mdst.; s.s., arg., silty, lt. greenish gray, v.f.-f. gr., well-mod. sorted; sltst., muddy, sl. sandy, greenish gray; int. as a whole shows reworking of lam., scour, micro-fract., acc. is glauc..	5664.5-5668.0

Thickness	Description	Depth (ft.)
0.8'	Intbd. sltst. and mdst., greenish gray to olive black, lam., org. remains (Antiarch scale, bone frag. and Pter*icthyodes*), uniform and no sedimentary structures.	5668.0-5668.8
5.0'	Dol. (70%), with some intbd. mdst. bands (30%); dol., arg., silty towards base, lt. olive gray to dk. greenish gray, aphanitic, shows lam., fract. and an erosional surface, scat. org. remains (Antiarch scale and ganoid type scale) in upper 1' of interval, acc. is pyrite.	5668.8-5673.8
2.5'	Mdst., sl. calc. near top, sl. anhy. near base, dk. greenish gray, org. remains (Cyzica) scat. throughout, acc. is pyrite associated with the org. remains.	5673.8-5676.3
6.1'	Anhy., arg., dk. greenish gray, shows brec. of lam. and micro fract., sub-lam. near base and lam. at top with most of brec. near center, also has cln. anhy. frag. as in other cores.	5676.3-5682.4

Mobil Nipisi 7-6-79-7W5 (KB 2180)

Core #1: 5595-5655 (rec. 60/60 ft.)

Thickness	Description	Depth (ft.)
Slave Point Fm.		
4.5'	Intbd., ls., dol. ls., and anhy.; ls., anhy. in part, dusky yellowish brown to med. lt. gray for anhy., arg. and sh. towards base and grades into next int., micro-crystalline to aphanitic, lam. and brec. in part, anhy. lam. are sl. brec., pinch and swell.	5595.0-5599.5
Top of Watt Mountain Fm.		
5.0'	Mdst., sh. and silty in part, partly calc. and anhy., dk. greenish gray to olive gray, anhy. pods and lam. in upper 1.5' show brec., uniform, acc. are mica and scat. pyrite, grades into next int..	5599.5-5604.5
0.7'	Sh., silty and sandy, calc., brownish gray to olive gray, sand and silt are in lam. which are v. sh., sub-lam., org. remains (Cyzica, Eochara wickendeni and Chovanella burgessi), abnt. mica and some scat. glauc., contact with next int. is sharp and based on color.	5604.5-5605.2
2.6'	Sltst., sandy, sh. micaceous, calc. with some anhy. pods, lt. gray for sandy parts to dk. greenish gray for sh. sltst. parts, lam., xlam., acc. is glauc..	5605.2-5607.8

Thickness	Description	Depth (ft.)
3.8'	Mdst., v. silty in part and partly sh., sl. calc., dk. greenish gray, micro fossils (Eochara wickendeni and Chovanella burgessi) and fish remains (Antiarch bone plate) in basal 0.6', acc. is glauc., becomes sandy near base and grades into next int..	5607.8-5611.6
2.5'	S.s., v. silty to sandy sltst., calc., v. arg., partly micaceous, greenish gray to olive dk. greenish gray, silty-v.c. gr., A.-r., v. poorly sorted, abnt. ls. frag. in basal 1.5' (up to 1.5 cm. long), cgl. band in upper 1" with fd. gr. up to 1 cm. (average 3-4 mm.), appears well reworked (mica has random orientations), lam. in basal part, scat. fish remains, comp. is 40% qtz., 40% fd., 10% mica, 10% rock frag., acc. is glauc..	5611.6-5614.1
1.8'	Mdst., silty and sandy, micaceous, calc., dk. greenish gray with brownish gray mot., uniform, mica is composed of muscovite and chlorite and is not as abnt. as in above int..	5614.1-5615.9
2.8'	S.s., arg., cgl. in part, lt. olive gray to med. gray, v.f.-gran. gr., A.-r., poorly sorted, lam., comp. is mainly qtz. and equal fd. with some mdst. chips in upper 1', acc. is mica, both upper and lower contact appear to be quite sharp.	5615.9-5618.7
0.8'	Mdst., sandy to v. dirty s.s., greenish gray to dk. greenish gray, org. remains (Antiarch bone plates), acc. is mica, grades into next int..	5618.7-5619.5
4.0'	S.s., arg. in part, partly calc., lt. olive gray to yellowish gray, f.-v.c. gr. with scat. gran., a.-R., poorly sorted, planar xbd., comp. is mainly qtz. and fd., acc. is mica.	5619.5-5623.5
1.0'	Sltst., sandy, arg. and sh. in part, calc., dk. greenish gray, sand gr. are v.f.-f. gr. and about 15% of interval, appears well reworked, uniform but more sandy at top than near base, acc. is mica, grades into next int..	5623.5-5624.5
8.9'	Mdst., scat. sand gr., dk. greenish gray with brownish gray mot., uniform, org. remains occur at: 5629.3-5630.5- Cyzica cf. membranacea 5632.0-5633.4- Cyzica cf. membranacea Antiarch scale and true fish scales acc. is mica, becomes sandy towards base and grades into next int..	5624.5-5633.4
2.8'	S.s., arg. in part, esp. in top 1' where there are some sh. bands, partly anhy. plugged, v. lt. gray to pinkish gray, f.-gran. gr., A.-r., poorly sorted, cgl. in part, sub-lam. in upper 1', comp. is qtz. and fd. with scat. rock frag., acc. is glauc..	5633.4-5636.2

Thickness	Description	Depth (ft.)
1.7'	Sltst., sandy in part, to silty s.s., calc., lt. greenish gray to greenish gray, appears well reworked, uniform, comp. is mainly qtz. and fd., acc. are mica and pyrite, grades into next int..	5636.2-5637.9
6.2'	Mdst., with a 2" sandy zone at 5643.1, calc., silty and sandy in basal 1', greenish gray with brownish gray mot. which appears to be due to brec. from 5641.6-5642.0, scat. fish remains at 5643, sand gr. in basal 1' are up to gran. size, comp. is qtz., fd. and ls. frag..	5637.9-5644.1
4.0'	Dol., anhy., arg. in part with some intbd. dol. mdst. lam., dk. yellowish gray to lt. olive gray, with olive black and greenish gray mdst. lam., aphanitic, shows pinch and swell, lam., slump, and anhy. replacement, grades into int. below.	5644.1-5648.1
1.4'	Mdst., dol., sandy in basal portion, olive gray to olive black, lam. in upper part, scat. fish remains, grades into int. below.	5648.1-5649.5
2.3'	Anhy., v. arg. to anhy. mdst., greenish gray to dk. greenish gray, has frag. of A.-R. cln. anhy. in it, R. frag. have yellowish orange and v. dk. red discoloration rims, upper 2"-3" is dol.and transition with int. above is gradational.	5649.5-5651.8
2.6'	Dol. or dol. ls., pale brownish yellow, aphanitic, stylolites at 5653', upper contact is brec. (may be due to movement of fluids during diagenesis), scat. sh. lam., basal few inches is greenish gray sh. which is sandy in part.	5651.8-5654.4

Abbreviations used in core descriptions

A- Rock type, modifiers, composition and accessories:

sh.	-shale (y)
mdst.	-mudstone
sltst.	-siltstone
s.s.	-sandstone
cgl.	-conglomerate (ic)
ls.	-limestone
dol.	-dolomite (ic)
anhy.	-anhydrite (ic)
arg.	-argillaceous
calc.	-calcareous
qtz.	-quartz
fd.	-feldspar
glauc.	-glauconite (ic)

B- Bedding and sedimentary structures:

bdg.	-bedding
intbd.	-interbedded (s)
xbd.	-cross-bedded
xbdg.	-cross-bedding
lam.	-laminated
xlam.	-cross-laminated
fract.	-fracture

C- Grain size and shape:

v.f.	-very fine
f.	-fine
m.	-medium
c.	-coarse
v.c.	-very coarse
gran.	-granule
pbl.	-pebble (y)
gr.	-grain (ed, s)
A.	-angular
a.	-subangular
r.	-subrounded
R.	-rounded
w.R.	-well rounded

(after Powers, 1953)

D- Others:

abnt.	-abundant
acc.	-accessories
appr.	-approximate (ly)
brec.	-brecciated (ion)
cln.	-clean
comp.	-composition
dk.	-dark
esp.	-especially
frag.	-fragment (ary)
ft.	-feet
int.	-interval
lt.	-light
mtx.	-matrix
med.	-medium
mod.	-moderately
mot.	-mottled (ing)
org.	-organic
o.s.	-oil stain (ing)
prob.	-probably
rec.	-recovery (ed)
scat.	-scattered
sl.	-slightly
w.r.t.	-with respect to

APPENDIX B

Sample Locations

Sample #	Well	Depth (ft.)
A: Size Analysis		
179	I.O.E. Sylvia 12-3-73-5W5	5430.0
182	"	5443.0
184	"	5454.0
186	"	5459.0
B: Thin Section Analysis		
122	I.O.E. Mitsue 12-7-73-4W5	5346.0
124	"	5348.8
125	"	5350.0
131	"	5359.5
133	"	5363.5
136	"	5369.0
179	I.O.E. Sylvia 12-3-73-5W5	5430.0
181	"	5437.5
182	"	5443.0
183	"	5448.0
184	"	5454.0
185	"	5456.5
186	"	5459.0
204	I.O.E. Mitsue 10-28-73-5W5	5400.5
210	"	5423.0
221	I.O.E. Sylvia 10-5-73-5W5	5492.5
224	"	5505.0
225	"	5509.0

Sample #	Well	Depth (ft.)
N-1	Mobil S.W. Nipisi 10-26-78-8W5	5653
N-2	"	5661
N-3	"	5663
N-4	"	5648
N-5	"	5671
N-6	"	5676
N-7	Mobil Nipisi 7-6-79-7W5	5617.8
N-8	"	5620.0
N-9	"	5621.9
N-10	"	5634.7

C: Mdst. Mineralogy

258)	I.O.E. Mitsue 4-4-73-4W5	(5310.5
)		(
259)	"	(5312.0
262	"	5320.5
263	"	5322.0
264	"	5324.0
266	"	5330.0
267	"	5331.5
268	"	5337.0
269)	"	(5339.0
)		(
270)	"	(5341.0
273	"	5348.5
274	"	5351.7